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GTD-AMP COMPUTER PROGRAM DESCRIPTION. USER'S MANUAL.(U)
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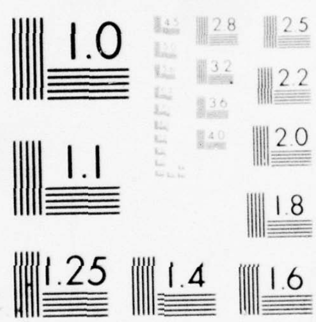

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Technical Report
February 1976

GTD-AMP COMPUTER PROGRAM DESCRIPTION
User's Manual

Ohio State University

Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York 13441

This report has been reviewed by the RADC Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be releasable to the general public including foreign nations.

This report has been reviewed and is approved for publication.

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This report describes the capabilities, limitations, and operation of the OSU, GTD-AMP Computer Code, which has been developed to calculate the electromagnetic radiation from currents on thin wires in the presence of a perfectly-conducting polygonal plate positioned over a reflecting surface of infinite extent. Although the code is based on the Geometrical Theory of Diffraction (GTD) it is designed to be compatible with the Antenna Modeling Program (AMP). The GTD-AMP program described herein is capable of handling many antenna-scattering

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problems once the currents on the wire radiators are known. Ordinarily these currents are found from the AMP program in the manner described in the text; however, they may be specified or obtained by other means. This combination of the moment method and GTD makes it possible to calculate radiation patterns which could not be calculated by either method individually.

CONTENTS

EVALUATION

This contractual effort resulted in the development of a geometrical theory of diffraction (GTD) computer code using the output of the antenna modeling program (AMP). This new GTD-AMP program analytically predicts the far field pattern of wire antennas above finite size ground planes taking into account the mutual coupling between current elements on the wire structure and the ground plane. The far field pattern also takes into account the edge diffraction from the finite ground plane.

The results of this effort provide a means of simulating the antenna and its environment more accurately than previously accomplished in the past. This fits into the RADC Technology Plan (TPO-5) for analytically simulating antenna systems to determine their effectiveness before fabrication and test.

The GTD-AMP computer code is presently operational on the RADC-HIS 635 computer facility and will be used to analyze the performance characteristics of radar and communication type antenna systems.

Carmen S. Malagisi
CARMEN S. MALAGISI
Project Engineer

I. PROGRAM CAPABILITIES

This document describes a computer program (referred to hereafter as the OSU or GTD-AMP program) which has been developed for the computation of the far field radiation from an arbitrary system of short current carrying wire segments situated above a flat polygonal plate which itself is located above a planar impedance surface or a dielectric medium bounded by a plane surface. The wire radiator-plate geometry is shown in Figure 1.

The wire radiator may have up to 300 segments (this number could easily be increased), which can be arbitrarily connected. The complex currents (e^{jwt} time convention) flowing on each wire segment are assumed to be already known. The wire segments may be arbitrarily located over the plate provided they are at least $\lambda/4$ away from the nearest edge.

We have shown that if the wire segments are located over the surface of the plate so that it is possible to drop a perpendicular from any point on the wire to the plate and are at least a quarter wavelength away from the plate edges, then the currents may be found quite accurately by replacing the finite polygonal plate with an infinite plate and then solving the resulting problem using moment methods [1]. Many computer codes exist which are capable of solving such a problem. One such code is the Antenna Modeling Program (AMP) [2]. The input format for our program conforms to that of the output from AMP. It is assumed that the wire segments are small enough so that the current flows axially along the wires and is constant over the length of one wire segment.

The flat, perfectly conducting polygonal plate may have up to 50 straight edges. The interior angles made by the intersecting edges must be less than 180°, i.e., the plate must be a convex polygon. The edges can be of any length and the wedge angle of each edge can be specifed by the user. This enables the user to model simple solid bodies.

The user may choose not to include the diffraction from one or more of the edges. This option makes it possible to model semi-infinite structures, since the diffraction from the edges at "infinity" may thus be excluded.

The infinite surface in the $z = 0$ plane can be used in three ways. First, it may be considered as an impedance surface and its complex normalized surface impedance specified. The normalized surface impedance z_s is defined by $E_y = -z_s\eta_o H_x$, $E_x = z_s\eta_o H_y$, where E_x, E_y, H_x, and H_y are evaluated on the x-y plane and $\eta_o = 377$ ohms. Special provisions for specifying the surface as a perfectly conducting groundplane have been made to avoid possible numerical difficulties. Second, the infinite half-space $z < 0$ may be filled with material of arbitrary permittivity and conductivity. This option might be used in modeling structures over the ocean or over lossy ground. Note that for any of the above cases only the fields in the $z > 0$ half-space are determined. Thirdly, the surface (and the entire $z < 0$ half-space) may be free space.

One of the options available to the user is to include only the

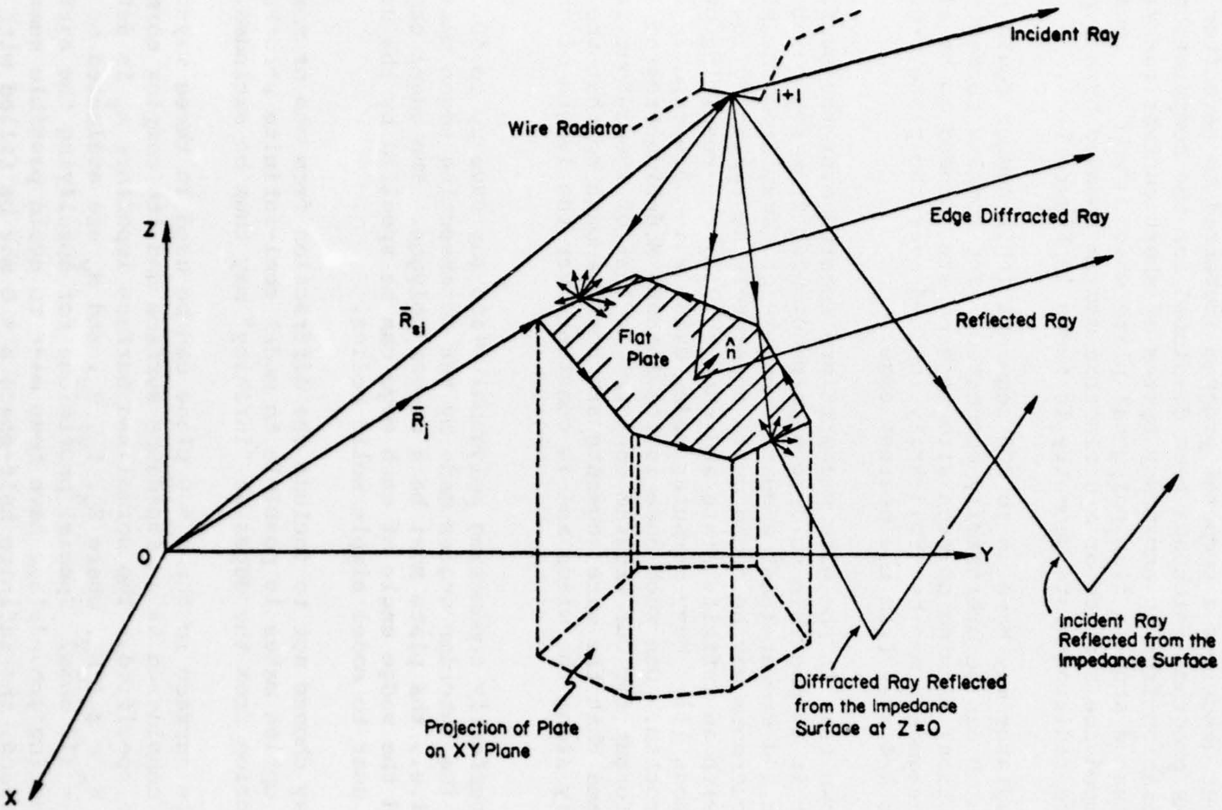

Figure 1. Conducting plate over impedance surface with all ray types included in the present computer code indicated. The impedance surface may be replaced by a dielectric halfspace, perfect conductor, or free space.

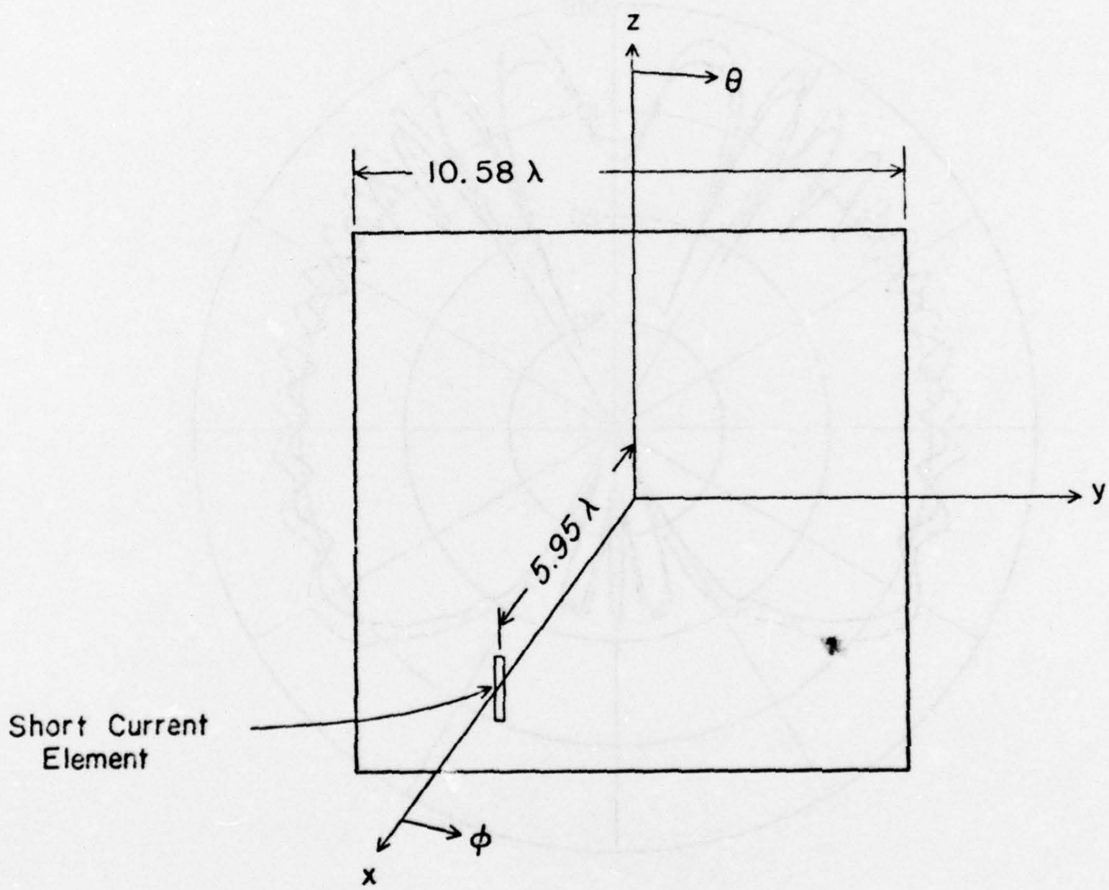

Figure 2. A square plate in the y-z plane illuminated by a current element centered over the plate. The frequency is 10.43 gHz.

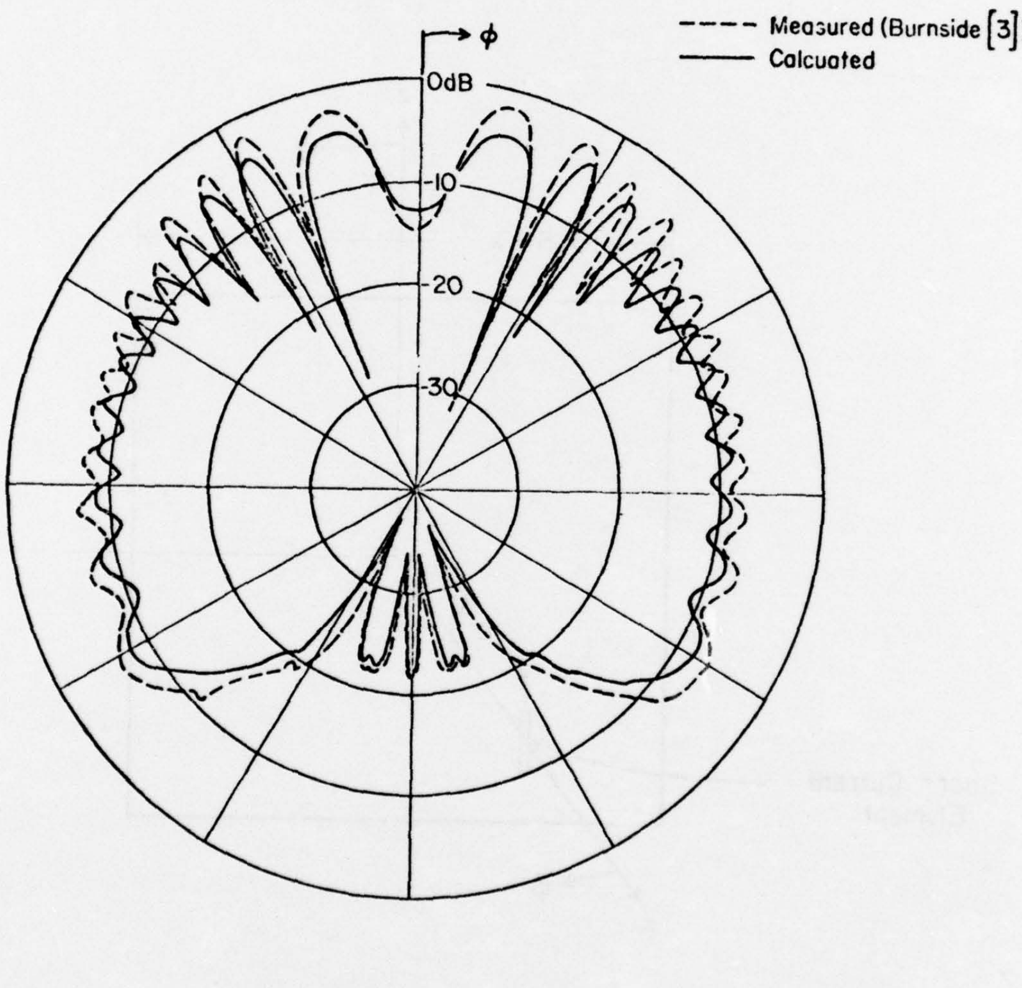

Figure 3. E_θ pattern in the x-y plane for the geometry of Figure 2.

scattered fields when summing the field contributions from the plate and surface. In this mode one (or more) current elements can be used to illuminate the plate/ground surface with the desired incident field. The program then calculates the scattered fields. Note that in this mode of operation the simultaneous use of a program such as AMP to find the segment currents is not required.

Another option available to the user is to specify calculation of only the diffracted fields. By comparing the diffracted field pattern with the total field pattern for the same geometry, one can quickly determine the dominant radiation mechanism for various pattern regions.

The user can control the output of the program by means of various input constants. If fields in dB are desired, one can obtain separately either the theta component, the phi component, or the total power of the radiated field in a given direction. This flexibility allows the user to obtain an output which is not cluttered with unwanted data when only one polarization is of interest. However, if desired, all of the above may be printed out. The normalization of the maximum dB level may also be controlled by means of input constants. If all three quantities are printed out, then all will be normalized in the same way so that comparisons between the three will be meaningful.

The complex electric field strengths in volts/meters for the two polarizations (θ and ϕ) can also be printed out for any point in space, provided the point is in the far field of the radiating structure.

Provisions have also been made for punched card output and for the control of possible visual displays of the calculated patterns which may be implemented at RADC.

The patterns may be computed with a fixed θ and variable ϕ, or vice versa. Additionally, the incremental angle between pattern data points may be controlled by the user.

A simple example of the type of geometry which can be handled by this program is shown in Figure 2. A radiating current element is located above a square plate. In Figure 3, the calculated radiation pattern in the x-y plane is compared with measured data [3]. The agreement is seen to be quite good.

II. PROGRAM LIMITATIONS

The GTD is basically a high frequency method. The user should be aware of the basic limitations of the present computer code, which includes only singly diffracted rays. This means that for accurate results the plate edges must be larger than one or two wavelengths and the current segments should be at least $\lambda/2$ away from the nearest edge. The plate size could be significantly reduced in an improved version including doubly-diffracted edge and vertex diffracted rays.

The omission of vertex diffracted rays from the computer code does not significantly affect pattern calculations such as the one in Figure 3 where the plane of the pattern cut is not near any of the plate corners. However, in Figure 4 we show a pattern calculation for the same geometry as Figures 2 and 3, but with the pattern cut in the plane of the plate. The discontinuities in the calculated patterns are caused by the lack of an adequate mathematical model for the diffraction from the corners of the plate. Useful data can still be obtained, but the user of the program should expect pattern discontinuities when a diffraction point is near a plate corner.

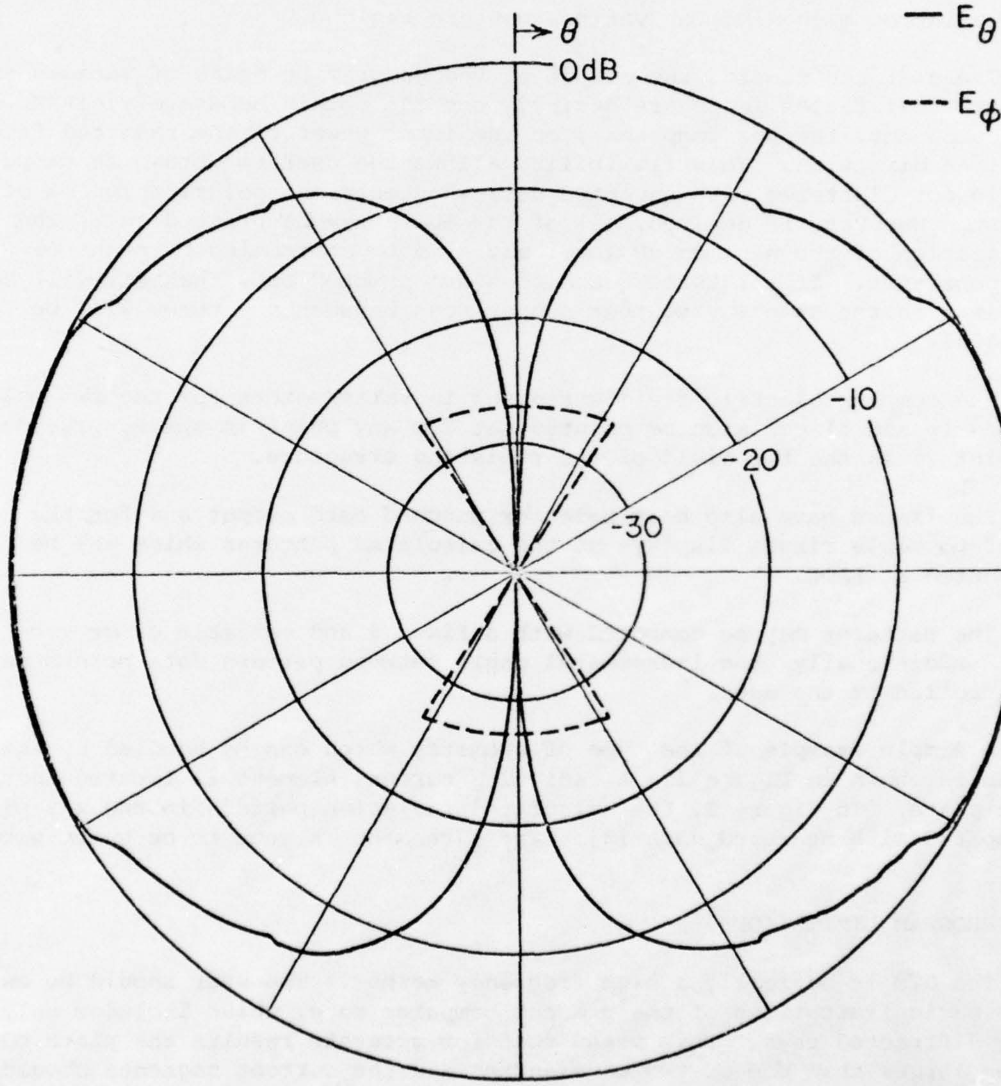

Figure 4. Calculated E_θ and E_ϕ patterns for geometry of Figure 2 in the yz plane.

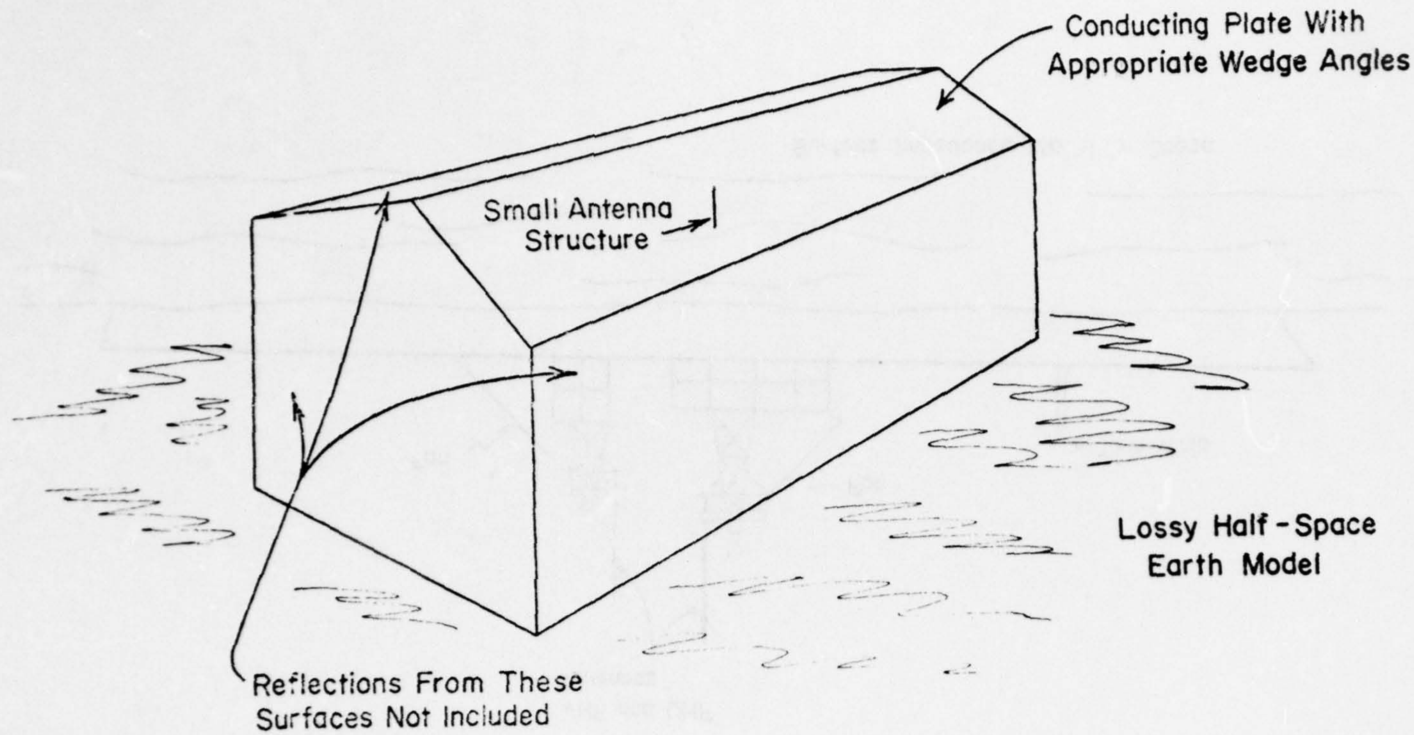

Figure 5. Example of modeling capabilities of present program. Antenna on metal-roofed building.

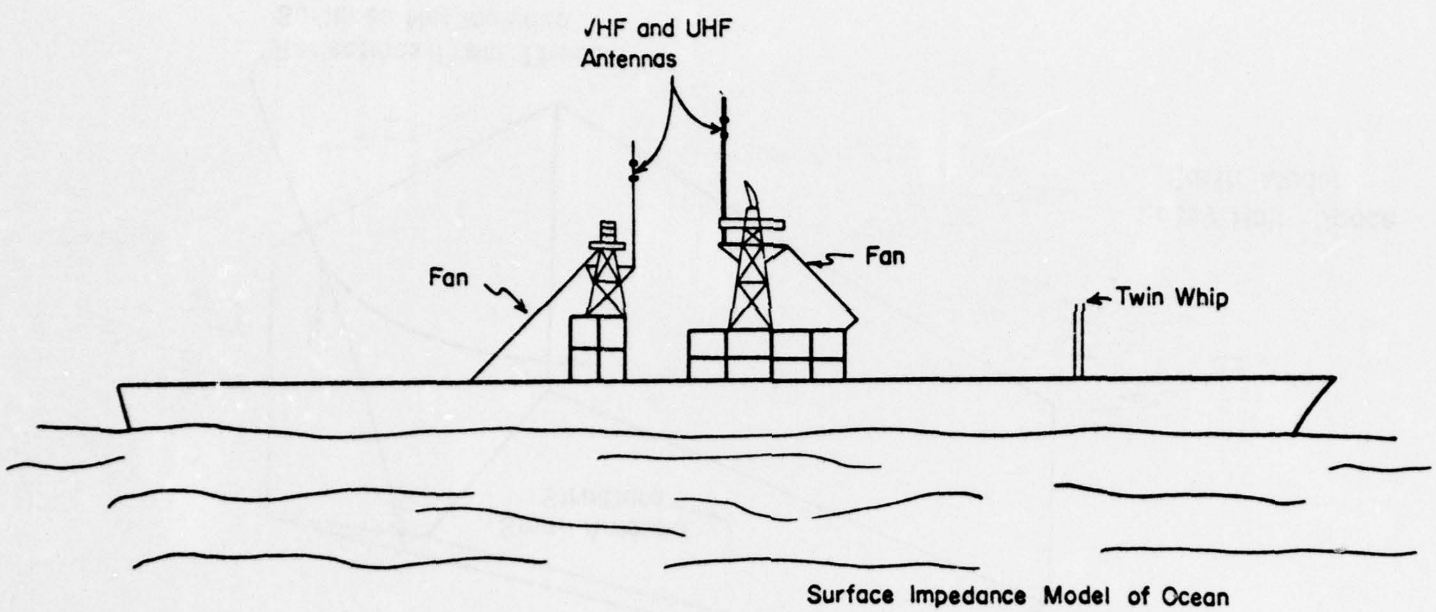

Figure 6. Example of ship and antennas which can be modeled using AMP and the AMP-GTD codes. AMP would be used to model the superstructure and antennas. Then the AMP-GTD code described in this publication would determine the effects of the ship's deck and the ocean surface on the antenna pattern.

As is the case with any numerical solution, numerical difficulties can arise if some of the distance or length parameters of the problem vary from one another by many orders of magnitude. To avoid these problems the user is cautioned to keep the plate and sources within 1,000 wavelengths of the origin and to let the plate edges and source distances differ by no more than 4 orders of magnitude.

When using the program to calculate diffracted or scattered fields far from the plate, one may find a discontinuity in the calculated field in the direction of the specular reflection. This is due to the vanishingly small angular width of this specular contribution in the far field, and the calculated field at that one angle is incorrect. The contribution is retained in the solution because it is needed in order to obtain correct results closer to the scatterer.

If the wire radiator is located between the plate and the ground plane (impedance surface or dielectric halfspace), the code will produce a calculated pattern; however, several types of rays which are not significant when the source is above the plate may be significant when the source is between the plate and the ground plane. Examples of such rays include rays reflected by the ground plane and diffracted by the plate, rays multiply reflected by the plate and the ground plane, and such rays eventually diffracted by the plate. Figure 1 illustrates all of the types of rays presently included in the code. If the problem geometry is such that other types of rays make significant contributions to the pattern, then the results obtained using this code will be more or less in error, depending on the relative importance of the the missing rays, and should be used with caution. It should be emphasized here that for the cases where the source is above the plate (or where no $z = 0$ plane discontinuity is present), the code does include all of the significant rays (subject to the constraints on plate size and corner diffraction previously mentioned).

Despite the limitations listed above, the present code is capable of calculating radiation patterns for some fairly realistic geometries. Two examples of this are shown in Figures 5 and 6.

III. PROGRAM DESCRIPTION

A description of the operation of the present computer code will be given in this section. A top level flow chart for the program is presented, and brief functional descriptions of the important subroutines will be provided.

As previously indicated, all of the types of rays included in the present code are shown in Figure 1. The computer code thus has two basic functions. First, it must decide whether or not any ray (or rays) of a given type exist. If so, it must then evaluate the electric fields associated with these rays. The results of the above process for each current segment are then added to produce the desired radiation pattern. It is evident that the

computations can actually be separated into two distinct parts: the geometrical problem of finding the contributing rays and the electromagnetic problem of evaluating the associated fields. We will see that the organization of the code is such that in many respects the two parts are treated distinctly, with different subroutines being used for the geometrical and electromagnetic calculations.

A top level flow chart of the main program (subroutines are excluded) is shown in Figure 7. From this it is evident that most of the actual calculations are performed in the subroutines. The various subroutines are extensively documented with comments which are distributed throughout the program listing. However, in order to provide an understanding of how the subroutines are logically interconnected, we will give brief descriptions of the basic subroutines ENGO, ETDIF and GROUND, list the subroutines which they call, and give brief descriptions of their purpose. These descriptions will be given in brief, blocked out form for easy reference.

ENGO: Calculates the direct and incident radiation fields.

ENGO calls subroutines EXIST, IMAGE, SOURCE.

EXIST: Determines whether or not the incident ray or reflected ray exists.

IMAGE: Determines the location of the image of a point through a plane.

SOURCE: Can compute either 1) the incident field at a diffraction point or 2) the far field of a source or image. When called by ENGO, function 2) is utilized.

Subroutine ENGO loops over all of the current segments. For each current segment it calls IMAGE to locate the image of the source in the plate, then calls EXIST to see if the ray from this image passes through the plate. If so, SOURCE is called to evaluate the field from the image location. To evaluate the direct radiation ENGO calls EXIST again to see if the ray from the source passes through the plate. If not, SOURCE is called to evaluate the field from the source location. The two contributions are added, and the next current segment in the DO loop is considered.

ETDIF: Calculates the total diffracted field.

ETDIF calls subroutine EMDIF.

EMDIF: Calculates the field diffracted (if any) by a given edge in a given direction when illuminated by a source at a given location.

Subroutine ETDIF loops over all of the current segments and all of the diffracting plate edges. Each time EMDIF is called to evaluate the diffracted field (if any). The results from EMDIF are summed to give the total diffracted field. (By total diffracted field, we mean the total field diffracted from the edges of the plate to the field point due to direct illumination of the edges by the current segments. Doubly diffracted fields or fields due to

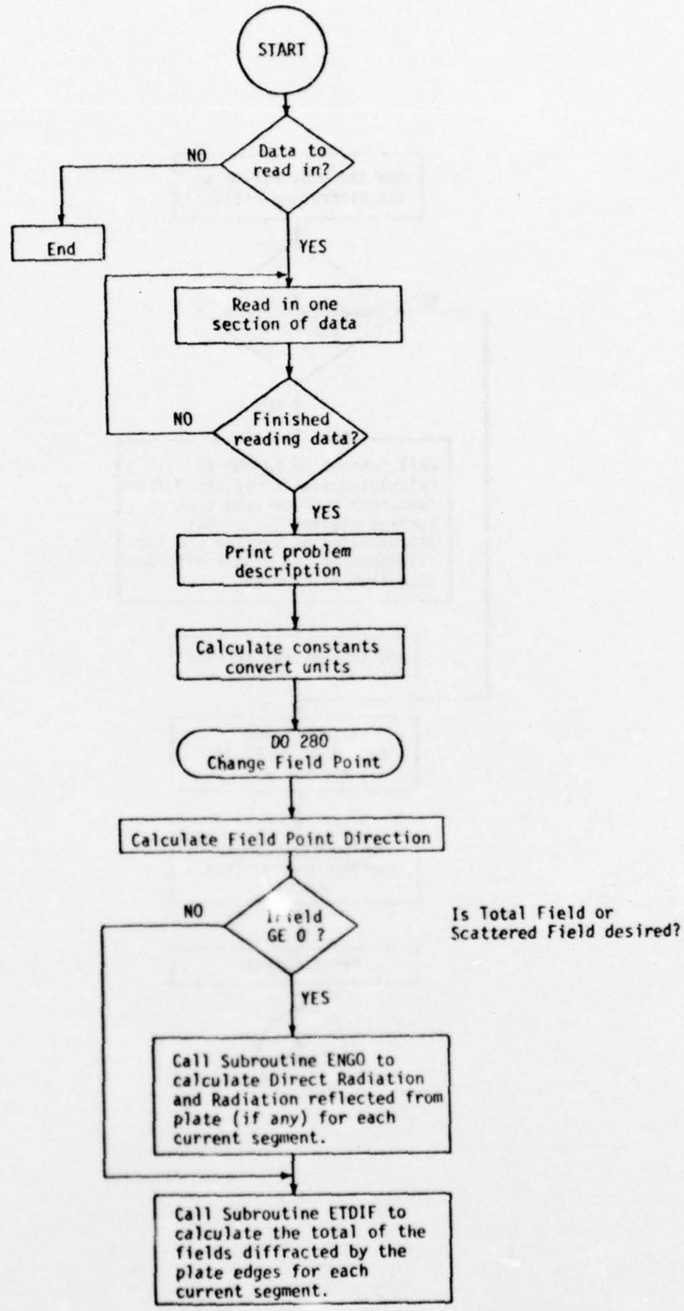

Figure 7. Top level flow chart for the GTD-AMP computer code.

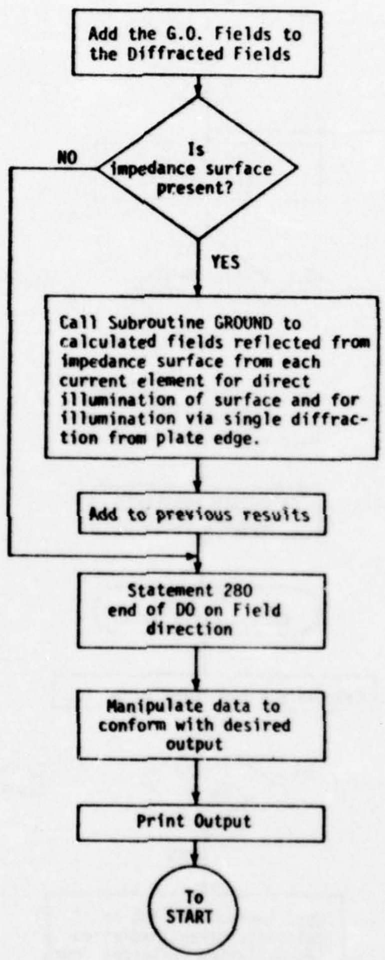

Figure 7 (continued). Top level flow chart for the GTD-AMP computer code.

reflections from the impedance surface are not included).

GROUND: Calculates the fields reflected from the impedance surface whether due to direct illumination by a current segment or illumination due to diffraction by a plate edge.

GROUND calls subroutine RFPN, SOURCE and EMDIF.

RFPN: Determines whether or not the ray reflected by the impedance surface in a given direction can exist.

Subroutine GROUND loops over all of the current segment sources. It calls subroutine RFPN to determine whether the reflected ray from a particular source exists. If so, subroutine SOURCE is called to evaluate the field from that particular source. Subroutine GROUND then loops over all of the edges (this loop is nested inside the source loop). For each edge EMDIF is called to calculate the diffracted-reflected field. Subroutine EMDIF itself makes use of the logic in RFPN to determine whether or not a given diffracted-reflected ray can exist.

The above information should provide the reader with an understanding of the basic organization of the program. For more detailed information the reader is referred to the program listing itself. As previously mentioned, this listing is liberally interlaced with comments which explain the working of the program in detail.

IV. INPUT/OUTPUT DESCRIPTION

The various coordinate systems which are used to specify the plate geometry and field point location are shown in Figure 8. The usual Cartesian (xyz) coordinates are used to locate each of the vertices of the flat polygonal plate. Each vertex is given a number, and the vertices are numbered consecutively (in either direction) around the plate. Each of the plate edges is also assigned a number (shown in parenthesis), with edge number K between vertices K and K + 1.

As mentioned previously, the diffracted fields from individual edges may be excluded from the calculations. This makes it possible to treat semi-infinite structures. For example, the model of an infinitely long strip shown in Figure 9 has the length of the strip much greater than the distance from the source to the strip, and the program can be directed to neglect the diffraction from edges (2) and (4). It should be noted that the plate must always have at least 1 diffracting edge.

The usual spherical coordinates (r, θ, ϕ) are also indicated in Figure 8, and these together with the ψ coordinate are used to specify the field point. The program allows for two types of pattern cuts: 1) conical (or planar) cuts where θ is held constant with ϕ varying between 0° and 360°, and

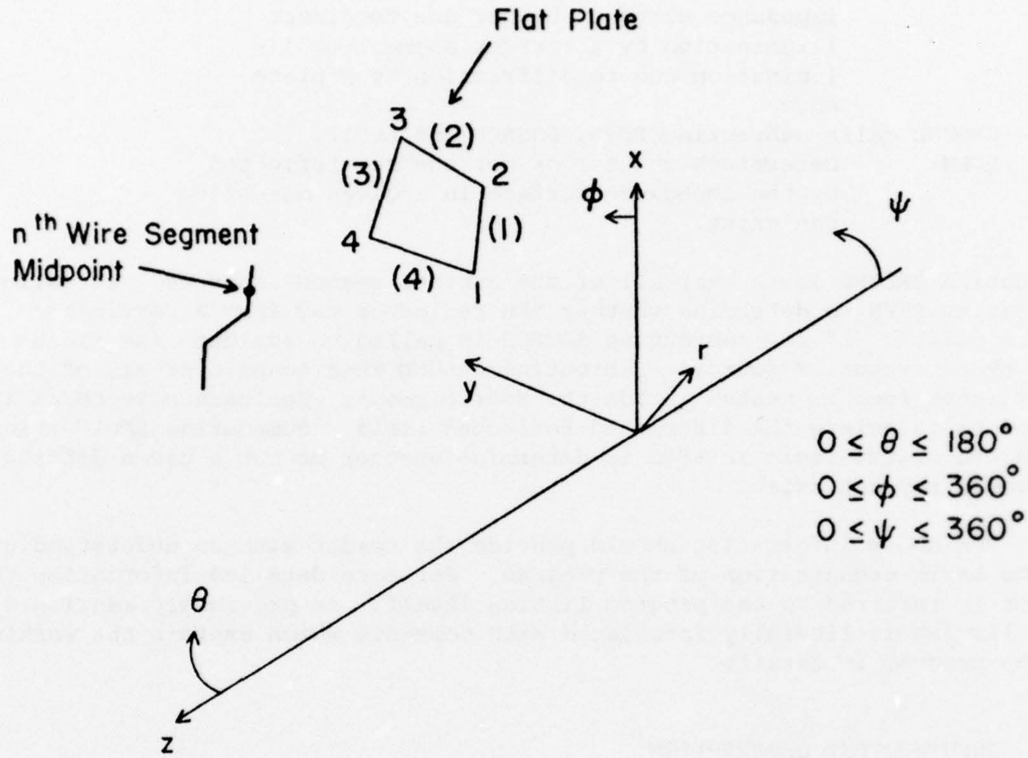

Figure 8. Coordinates used to specify the plate vertices, current elements and field point.

2) planar cuts with ψ varying between 0° and 360°. The additional coordinate ψ is introduced to avoid the difficulty involved in making a complete circle around the radiating structure with ϕ constant. This difficulty arises because θ is usually constrained so that $0 \le \theta \le 180^{\circ}$. The plane of the pattern cut for patterns of type 2) is determined by the z axis and the point specified by the r value and the initial ψ and ϕ values. This point also determines the positive ψ direction in the plane (i.e., from the negative z axis toward the initial point). The value of r given for the field point should be in the far zone, i.e., it should be far enough away from the radiating structure so that all rays from the structure toward the field point are essentially parallel. Generally, this condition can be obtained if $r > 2D^2/\lambda$, where D is the maximum extent of the radiating system including all wire elements, plate edges, and all image points. Phase is referenced to the origin of the xyz coordinates.

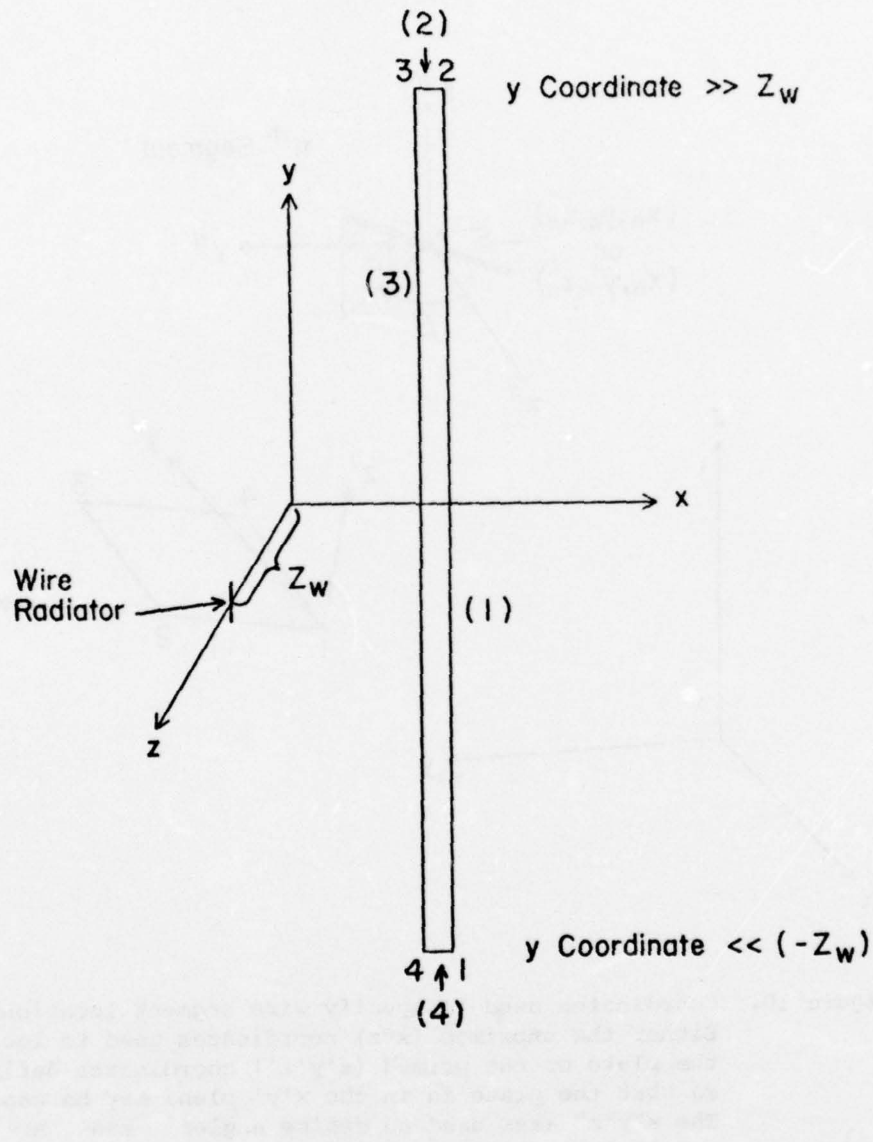

Figure 9. Modeling infinite conducting strip with rectangular plate. The diffraction from edges (2) and (4) can be explicitly excluded from the computations.

The center of each radiating current segment is specified using Cartesian coordinates as illustrated in Figure 10. Either the unprimed (xyz) coordinates used to locate the plate vertices or the primed (x'y'z') coordinates defined by the plate location may be used. This second coordinate

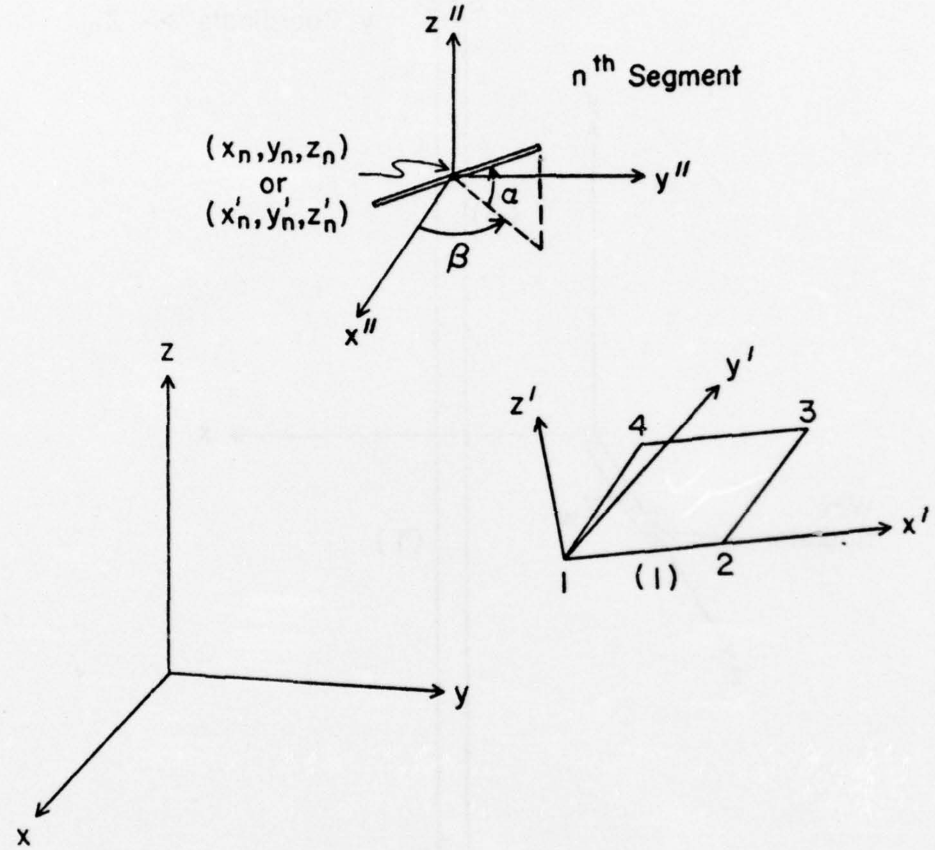

Figure 10. Coordinates used to specify wire segment locations. Either the unprimed (xyz) coordinates used to locate the plate or the primed (x'y'z') coordinates defined so that the plate is in the x'y' plane may be used. The x"y"z" axes used to define angles and are parallel to whichever coordinate system (primed or unprimed) is chosen.

system is added so that coordinates from the AMP program, which requires that the ground plane coincide with the x-y plane, can be fed directly into the present code. The primed coordinates are defined with z' perpendicular

to the plane of the plate and x' along edge (1), with the origin at vertex 1.

The orientation of each segment is specified by the α and β angles shown in Figure 10, where x", y" and z" are parallel to the coordinate system axes used to specify the segment center (either x, y, z or x', y', z'). This specification of the wire segment location is the same as that used in the output of AMP.

The connection data and tag numbers used by AMP may be input to the code, if desired. This information will then be printed out for identification purposes. However, this data is not needed or used by the OSU code.

We will now describe in detail the format of the input cards which control the operation of the code. The input data will consist of a section of comments and four numerical input sections. The comments section is a set of comment cards which enable the user to print out a description of the problem. Each comment card starts at column 1 with an asterisk sign (*), except the last comment card which must begin with a period sign (.). At least one comment card must be included in the input data set. After the comments are the following sections:

- -1 Plate data,
- -2 Source data,
- -3 Pattern control,
- -4 Output control.

All four sections need not be included. However, those included must be in the above order.

The first card of each section identifies the section number at column 15. Columns 1-10 are for identification, which can contain any combination of characters to help the user to identify the card. The contents of columns 1-10 do not have any effects on the computer code and will be referred to as the identification field. A number "1" in column 20, whenever it appears on the first card in a section, indicates that the program will be executed right after reading that section's data; otherwise, the data of the next section will be read following that of the present section. For more details, refer to the discussion on modification of input data.

A. Plate Data

Following the plate data section card (1 in column 15) is the plate data, which includes three types of cards besides the section card. These three types of cards appear in the following order:

--One card to specify the number of edges of the plate (M) and the number of diffracting edges (ME). It is usual to have M = ME, except for some special cases in which the diffracted fields from certain edges are not included.

The format is (10x, 215); 10x is the field used for identifying comments.

--A second card (included only when ME is less than M) is to specify the diffracting edges by edge numbers, one number for each diffracting edge. The format is (10x, 1415) and it can be continued on other cards.

--A third type of card (one card for each vertex) is to specify the positions (x, y, z) of the vertices and the corresponding wedge angle. The format is (10x, 4F10.5). The position of one vertex and the wedge angle for the edge between that vertex and the next is contained on one card. The ordering of vertices is described in Figure 2 and must be applied. All dimensions are in meters.

--The last card in this section is used to specify the impedance surface parameters. The Format is (10x, I5, 2E12.4). The integer variable IGND in the I5 field may be coded in one of three ways: IGND = 0, no impedance surface, i.e., free space everywhere; IGND = 1, dielectric halfspace for $z < 0$; IGND = 2, impedance surface at $z = 0$. For IGND = 1, the relative permittivity ε_r and the conductivity σ (mhos/meter), respectively, are coded into the two E12.4 fields. For IGND = 3, the real and imaginary parts of the surface impedance z_s (normalized to that of free space) are coded into the two E12.4 fields. However, if ε_r and σ (or z_s) are equal to zero, the $z = 0$ surface will be treated as a perfectly conducting ground plane. (These zero values are then not related to physical properties, but serve only to input into the code the information that the x-y plane should be treated as a perfect conductor).

B. Source Data

Following the Source Data Section card (2 in column 15) are three types of data cards:

--Number of current segments $|N|$ and coordinate system used -- N negative for primed system; positive for unprimed. Format (10x, 15).

--Segment positions: one card for each segment. On each card: position of midpoint (x, y, z) or (x', y', z'), length, angles alpha and beta, and the connection data (optional). Format (6F10.5), 415).

--Complex segment currents, rectangular form, format (2E12.4). Again there is one card for each current segment. The order must correspond with that of the above segment position cards.

C. Pattern Control

Following the Pattern Control Section card (3 in column 15) is the input card which controls the pattern calculations and frequency. It is formatted (10x, 5F10.5, E11.4). The input variables and descriptions, in the order in which they are read, are listed below:

AI	the initial (ϕ or ψ) pattern angle
AF	the final (ϕ or ψ) pattern angle
DEL	the angle increment
PHITHE	the fixed (θ or ϕ) pattern angles. If PHITHE is negative, it denotes a fixed θ; if positive or zero, a fixed ϕ. ($\theta = \lvert PHITHE \rvert$).
FR	frequency in gigahertz; if FR = 0, the default frequency of .3 gHZ is used (the wavelength is then 1 m, so that all lengths can be input as wavelengths).
RA	radial distance from center of coordinate system to field point; if RA = 0, then the default value of 10,000 wavelengths is used. Note that the radial distance specified must be in the far field of the source-plate geometry for accurate results.

D. Output Control

The output control portion of the input data consists of the section card (4 in column 15) followed by one card, formatted (10x, 8I5, F10.5). The control variables on this card, in the order in which they are coded, are:

--IOUT1: If only the θ component pattern or only the ϕ component pattern or only the power pattern is desired, then this variable is set to a non-zero integer value as *follows:*

1 for θ component of pattern in dB,
2 for ϕ component of pattern in dB,
3 for power pattern in dB.

The individual component selected will have a max value in dB equal to FACTOR (described below). If IOUT1 = 0, none of the individual patterns listed above are printed out.

--IOUT2: If all three of the above patterns are of interest, then set IOUT2 = 1. This will result in the θ and ϕ component patterns and the power pattern being printed out in dB. All three will be normalized identically, so that comparisons between the three components will be meaningful.

The maximum value of the power pattern will be equal to FACTOR. If IOUT2 = 0, the three components will not be printed out.

--IOUT3: If complex electric fields are desired, then set IOUT3 as follows:

IOUT3 = 1	will output the complex θ and ϕ components of the electric field in rectangular form
IOUT3 = 2	will output the complex θ and ϕ components of the electric field in polar form

If the complex electric fields are not desired, set IOUT3 = 0.

--JOUT1, JOUT2, JOUT3: If any of these variables are set = 1, the corresponding (IOUT1, IOUT2, IOUT3) field quantities will be punched on cards. If card output is not desired, set them = 0.

--JOUT4: This variable reserved for control of plotting routines which may be implemented at RADC.

--IFIELD: Determines the nature of the calculated fields:

-1 for diffracted field only,
0 for total field,
1 for scattered field only.

--FACTOR: Maximum value for dB patterns controlled by IOUT1 and IOUT2. See the discussion above.

E. Modification of Input Data

The computer code is designed to handle many different problems at each run. If certain data sections do not vary from one problem to the next, the data need not be read in again. After the first problem, the data set need only consist of the introduction (comments) section and the modified data sections. The last section of modified data to be read in for each problem should contain a 1 punched in column 20 of the section card. The remaining cards of that section will be read and the program will then begin calculations for that problem.

V. SAMPLE COMPUTER RUNS

In this section we will present four sample runs of the present OSU program. Each sample will be complete with input cards and program output listed. The first three samples will be cases where the desired results can be obtained without using AMP to find the currents. The last case will first utilize AMP to find the currents (the AMP output is included) and then

the currents will be input into the OSU code for pattern calculations.

A. Current Element Above a Square Plate

The first sample run will correspond to the geometry of Figure 2, and the pattern cut will produce the pattern of Figure 3. The input card listing and program output are shown in the next pages. Since this is our first example, a brief discussion of the input data stream is appropriate. The prospective user should follow this discussion with reference to the previous section of this report.

The first five cards are comment cards used to identify the run. The last comment card starts with a period. Following these cards the actual input is divided into four sections by the section cards which begin with the word "SECTION" (optional -- for user identification) and are identified by number in column 15.

Section 1 is concerned with the plate and ground plane data. For this problem the plate has 4 edges, all 4 of which may contribute to the diffracted fields. Each vertex is given, and the interior wedge angle (left blank) is 0.0° for each edge. No impedance surface is present.

In Section 2 the number of current segments (1 in this case), their position, and the complex current flowing on each is given.

In Section 3 the pattern control data is given. For this run θ is fixed at 90° (x-y plane) while ϕ varies from 0° to 360° in 5° increments. The frequency and the distance from the origin to the field point are given.

In Section 4 the program is directed to produce a printed output consisting of the θ and ϕ components in dB with a maximum value of 00.0 dB and also the complex electric field (polar form) for both the θ and ϕ components. The total field will be calculated.

The corresponding output is listed following the input card listing.

Case A Input

```
*PROBLEM :
*SHORT DIPOLE ABOVE FLAT PLATE
*PLATE IS 12" SQUARE
*DIPOLE IS 6.75" ABOVE THE PLATE & IN THE CENTER
.FREQUENCY IS 10.43 GHZ
SECTION            1
NO. EDGES       4     4
VERTEX     0.0        0.15240     -0.1524
VERTEX     0.0        0.15240      0.1524
VERTEX     0.0        -.15240      0.1524
VERTEX     0.0        -.15240     -0.1524
NO GROUND          0
SECTION            2
# SEGMENT          1
0.1714     0.0        0.0         0.01       90.         0.
  1.0000E+00  0.0000E+00
SECTION            3
PATTERN    0.0        360.        5.         -90.        10.43       +1.0000E+05
SECTION            4
OUTPUT             0     1     2     0     0     0     0     00.0
```

Case A Output

```
PROBLEM :
SHORT DIPOLE ABOVE FLAT PLATE
PLATE IS 12" SQUARE
DIPOLE IS 6.75" ABOVE THE PLATE & IN THE CENTER
THE FREQUENCY IS 10.43 GHZ
```

```
********************************
*            UNITS             *
*            -----             *
*                              *
*        LENGTH : METERS       *
*         PHASE : DEGREES      *
* ELECTRIC FIELD : VOLTS/METER *
*       PATTERN : DB           *
*     FREQUENCY =  10.43COGHZ  *
*    WAVELENGTH =   0.0288 M   *
********************************
```

POSITION OF VERTICES AND CORRESPONDING WEDGE ANGLES

X	Y	Z	ANGLES	EDGE NUMBER
0.0	0.1524	-0.1524		
0.0	0.1524	0.1524	0.0	1
0.0	-0.1524	0.1524	0.0	2
0.0	-0.1524	-0.1524	0.0	3
0.0	0.1524	-0.1524	0.0	4

- - - - SEGMENTATION DATA - - - -

I+ AND I- INDICATE THE SEGMENTS BEFORE AND AFTER I

SEG. COORDINATES OF SEG. CENTER SEG. ORIENTATION ANGLES CONNECTION DATA TAG - - - - CURRENT - - - -

NO.	X	Y	Z	LENGTH	ALPHA	BETA	I-	I	I+	NO.	REAL	IMAG.
1	0.17140	0.0	0.0	0.01000	90.000	0.0	0	0	0	0	0.1000E+01	0.0

PATTERN OF TOTAL FIELD

THETA	PHI	NORMALIZED POWER GAIN E-THETA	E-PHI	TOTAL
90.00	0.0	-8.2127	-141.4671	-8.2127
90.00	5.00	-7.0026	-145.9919	-7.0026
90.00	10.00	-1.2992	-149.0252	-1.2992
90.00	15.00	0.0	-139.6600	0.0
90.00	20.00	-3.6363	-136.1628	-3.6363
90.00	25.00	-3.8203	-139.0121	-3.8203
90.00	30.00	-1.0734	-129.8201	-1.0734
90.00	35.00	-2.2197	-254.8661	-2.2197
90.00	40.00	-7.9039	-252.2403	-7.9039
90.00	45.00	-1.8019	-254.5593	-1.8019
90.00	50.00	-5.6581	-257.9865	-5.6581
90.00	55.00	-6.1307	-261.0305	-6.1307
90.00	60.00	-3.3490	-263.9866	-3.3490
90.00	65.00	-5.3887	-266.9396	-5.3887
90.00	70.00	-5.7303	-269.7424	-5.7303
90.00	75.00	-3.7474	-272.9502	-3.7474
90.00	80.00	-6.0633	-276.9517	-6.0633
90.00	85.00	-4.3095	-283.6116	-4.3095
90.00	90.00	-5.2291	-376.7432	-5.2291
90.00	95.00	-4.5479	-283.2507	-4.5478
90.00	100.00	-5.5898	-276.9517	-5.5898
90.00	105.00	-3.8454	-272.9502	-3.8454
90.00	110.00	-6.2647	-269.4851	-6.2647
90.00	115.00	-5.0041	-265.7666	-5.0041
90.00	120.00	-3.3180	-263.9866	-3.3180
90.00	125.00	-3.9270	-261.0305	-3.9270
90.00	130.00	-6.2889	-257.8865	-6.2889
90.00	135.00	-9.3193	-254.5593	-9.3194
90.00	140.00	-12.2792	-252.2404	-12.2792
90.00	145.00	-15.5211	-254.8661	-15.5211
90.00	150.00	-22.8042	-129.9563	-22.8042
90.00	155.00	-30.8419	-138.5047	-30.8419
90.00	160.00	-23.7670	-139.2598	-23.7670
90.00	165.00	-17.7827	-140.4077	-17.7827
90.00	170.00	-17.4950	-140.7921	-17.4950
90.00	175.00	-27.9715	-145.6693	-27.9715
90.00	180.00	-16.6386	-236.9281	-16.6386
90.00	185.00	-27.9715	-147.1563	-27.9715
90.00	190.00	-17.4950	-142.5540	-17.4950
90.00	195.00	-17.7827	-138.4982	-17.7827
90.00	200.00	-23.7670	-134.0898	-23.7670
90.00	205.00	-30.8419	-133.4367	-30.8419
90.00	210.00	-22.8040	-138.0043	-22.8040
90.00	215.00	-15.5211	-268.4443	-15.5211
90.00	220.00	-12.2792	-268.7295	-12.2792
90.00	225.00	-9.3194	-268.9797	-9.3194
90.00	230.00	-6.2888	-269.1960	-6.2888
90.00	235.00	-3.9270	-269.3838	-3.9270
90.00	240.00	-3.3180	-269.5427	-3.3180
90.00	245.00	-5.0041	-270.8855	-5.0041
90.00	250.00	-6.2647	-269.7837	-6.2647

90.00	255.00	-3.8454	-269.8662	-3.8454
90.00	260.00	-5.5898	-269.8508	-5.5898
90.00	265.00	-4.5478	-269.9597	-4.5478
90.00	270.00	-5.2290	-269.9712	-5.2290
90.00	275.00	-4.3095	-269.9597	-4.3095
90.00	280.00	-6.0633	-269.8508	-6.0633
90.00	285.00	-3.7474	-269.8662	-3.7474
90.00	290.00	-5.7303	-269.7837	-5.7303
90.00	295.00	-5.3887	-270.8855	-5.3887
90.00	300.00	-3.3490	-269.5437	-3.3490
90.00	305.00	-6.1306	-269.3838	-6.1306
90.00	310.00	-5.6581	-269.1960	-5.6581
90.00	315.00	-1.8019	-268.9797	-1.8019
90.00	320.00	-7.9039	-268.7295	-7.9039
90.00	325.00	-2.2198	-268.4443	-2.2198
90.00	330.00	-1.0734	-139.7533	-1.0734
90.00	335.00	-3.8205	-133.6621	-3.8205
90.00	340.00	-3.6363	-134.2799	-3.6363
90.00	345.00	0.0	-138.5611	0.0
90.00	350.00	-1.2992	-143.1485	-1.2992
90.00	355.00	-7.0026	-148.0204	-7.0026
90.00	360.00	-8.2127	-151.6568	-8.2127

TOTAL FIELD AT R = 0.1000E+06 METERS

THETA	PHI	THETA COMPONENT AMPLITUDE	THETA COMPONENT PHASE	PHI COMPONENT AMPLITUDE	PHI COMPONENT PHASE
90.00	0.0	0.129683E-04	18.48	0.275535E-11	-122.22
90.00	5.00	0.149074E-04	5.09	0.167469E-11	147.93
90.00	10.00	0.287459E-04	8.81	0.118105E-11	160.31
90.00	15.00	0.333836E-04	0.67	0.347164E-11	-87.18
90.00	20.00	0.219644E-04	-5.62	0.519270E-11	-48.11
90.00	25.00	0.215039E-04	-177.89	0.374045E-11	36.35
90.00	30.00	0.205030E-04	179.64	0.107770E-10	165.65
90.00	35.00	0.258553E-04	12.47	0.602875E-17	-89.26
90.00	40.00	0.134391E-04	-32.71	0.815672E-17	55.55
90.00	45.00	0.271294E-04	168.74	0.624546E-17	-[illegible].29
90.00	50.00	0.174032E-04	10.40	0.425796E-17	99.97
90.00	55.00	0.164816E-04	-105.71	0.296485E-17	-166.40
90.00	60.00	0.227031E-04	84.85	0.210962E-17	-81.73
90.00	65.00	0.179515E-04	-94.02	0.151896E-17	-7.80
90.00	70.00	0.172501E-04	111.76	0.109733E-17	54.[illegible]3
90.00	75.00	0.216851E-04	-75.36	0.751659E-18	102.93
90.00	80.00	0.16610[illegible]E-04	97.41	0.474186E-18	138.32
90.00	85.00	0.203264E-04	-76.63	0.220269E-18	159.94
90.00	90.00	0.182844E-04	82.20	0.485700E-23	166.93
90.00	95.00	0.197763E-04	-89.64	0.220600E-18	-[illegible].31
90.00	100.00	0.175406E-04	69.89	0.474179E-18	-41.69
90.00	105.00	0.214419E-04	-101.90	0.751653E-18	-77.07
90.00	110.00	0.162292E-04	81.00	0.125680E-17	-125.50
90.00	115.00	0.187641E-04	-107.38	0.171869E-17	171.55
90.00	120.00	0.227843E-04	97.07	0.210951E-17	98.27
90.00	125.00	0.212414E-04	-48.32	0.296484E-17	13.59
90.00	130.00	0.161842E-04	168.80	0.425794E-17	-90.02
90.00	135.00	0.114174E-04	27.65	0.624546E-17	179.71
90.00	140.00	0.812031E-05	-116.59	0.815667E-17	-123.45
90.00	145.00	0.559086E-05	93.39	0.602877E-17	90.74
90.00	150.00	0.241727E-05	4.37	0.107330E-10	-17.89

90.00	155.00	0.958156E-06	-55.92	0.392314E-11	-150.46
90.00	160.00	0.216362E-05	-96.10	0.363531E-11	116.97
90.00	165.00	0.430923E-05	174.78	0.318526E-11	87.95
90.00	170.00	0.445435E-05	81.23	0.304739E-11	37.99
90.00	175.00	0.133339E-05	82.85	0.173906E-11	-36.35
90.00	180.00	0.491592E-05	56.72	0.475469E-16	-51.67
90.00	185.00	0.133339E-05	82.95	0.146458E-11	94.45
90.00	190.00	0.445434E-05	81.23	0.245942E-11	146.31
90.00	195.00	0.430923E-05	174.78	0.396847E-11	-141.99
90.00	200.00	0.216364E-05	-96.10	0.659237E-11	-60.54
90.00	205.00	0.958154E-06	-55.92	0.710725E-11	30.26
90.00	210.00	0.241731E-05	4.37	0.420068E-11	108.70
90.00	215.00	0.559096E-05	93.39	0.126271E-17	40.90
90.00	220.00	0.812030E-05	-116.59	0.122194E-17	-91.17
90.00	225.00	0.114173E-04	27.65	0.118726E-17	144.11
90.00	230.00	0.161842E-04	168.80	0.115826E-17	33.21
90.00	235.00	0.212413E-04	-48.33	0.113327E-17	-69.09
90.00	240.00	0.227843E-04	97.07	0.111262E-17	-157.50
90.00	245.00	0.187641E-04	-107.38	0.953346E-18	117.74
90.00	250.00	0.162292E-04	81.00	0.108228E-17	61.99
90.00	255.00	0.214418E-04	-101.90	0.107204E-17	11.95
90.00	260.00	0.175436E-04	69.89	0.107396E-17	-24.25
90.00	265.00	0.197763E-04	-89.64	0.106357E-17	-45.79
90.00	270.00	0.182844E-04	82.20	0.105916E-17	126.95
90.00	275.00	0.203264E-04	-76.64	0.106057E-17	134.21
90.00	280.00	0.166101E-04	97.40	0.107396E-17	155.75
90.00	285.00	0.216851E-04	-75.36	0.107204E-17	-168.05
90.00	290.00	0.172590E-04	111.76	0.108229E-17	-118.01
90.00	295.00	0.179515E-04	-94.02	0.953346E-18	-62.26
90.00	300.00	0.227031E-04	84.85	0.111262E-17	22.55
90.00	305.00	0.164817E-04	-105.71	0.113327E-17	111.91
90.00	310.00	0.174032E-04	10.40	0.115806E-17	-146.79
90.00	315.00	0.271294E-04	168.74	0.118726E-17	-33.89
90.00	320.00	0.134381E-04	-32.71	0.122194E-17	88.83
90.00	325.00	0.258549E-04	12.47	0.126271E-17	-139.17
90.00	330.00	0.295230E-04	179.64	0.343455E-11	-67.95
90.00	335.00	0.215034E-04	-177.88	0.692510E-11	-144.35
90.00	340.00	0.219644E-04	-5.62	0.644966E-11	124.95
90.00	345.00	0.333836E-04	0.67	0.393987E-11	43.83
90.00	350.00	0.287459E-04	8.81	0.232331E-11	-27.77
90.00	355.00	0.149074E-04	5.09	0.132590E-11	-85.39
90.00	360.00	0.129688E-04	18.48	0.872349E-12	-122.22

B. Current Element On Step

The geometry for this problem is shown in the insert of Figure 11. We wish to find the radiated fields. This is a two-dimensional problem which can be solved quite easily using the GTD. The step structure can be modeled by the GTD-AMP computer code by letting the plate form the top surface of the step and the infinite ground plane form the lower surface. The vertical surface can not actually be modeled. However, all of its effects can be included by specifying that the plate have a 90° wedge angle. Since the original problem has only one diffracting edge, the GTD-AMP code is directed to include diffraction effects from only the corresponding plate edge. The other edges are specified to be far from the current element so that the semi-infinite nature of the original problem is closely approximated. The input data and corresponding output appear on the following pages.

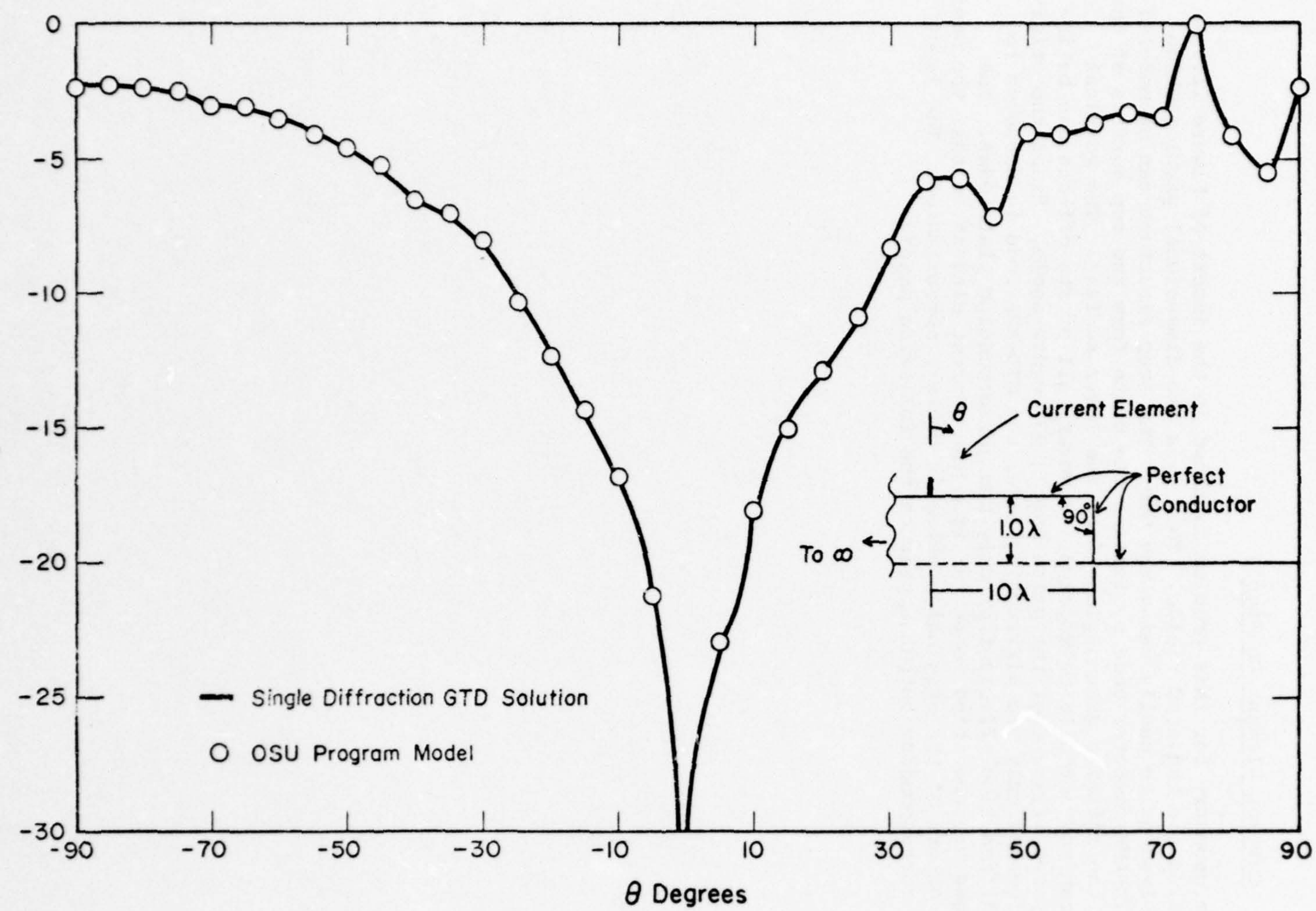

Figure 11. Calculated radiation pattern for a current element on a step. (The curve is drawn through points calculated at 5^{o} intervals; hence, some fine structure is missing).

Case B   Input

```
.STEP STRUCTURE
SECTION        1
NO. EDGES      4    1
DIFF. EDGE     2
VERTEX     999.       -999.       1.         90.
VERTEX     999.       0.0         1.         90.
VERTEX    -999.       0.0         1.         90.
VERTEX    -999.       -999.       1.         90.
GROUND PL.     1  0.0000E+00  0.0000E+00
SECTION        2
# SEGMENT      1
0        -10.       1.001      .002       90.        0.0
  1.0000E+00  0.0000E+00
SECTION       3
PATTERN   90.       270.      5.        270.       0.0        +1.0000E+05
SECTION        4
OUTPUT         0    1    2    0    0    0    0    00.0
```

Case B   Output

STEP STRUCTURE

```
*********************************
*             UNITS             *
*             -----             *
*      LENGTH : METERS          *
*       PHASE : DEGREES         *
* ELECTRIC FIELD : VOLTS/METER  *
*     PATTERN : DB              *
*   FREQUENCY =    0.3000GHZ    *
*  WAVELENGTH =    1.0000 M     *
*********************************
```

HALF SPACE BELOW X-Y PLANE :

X-Y PLANE IS PERFECT CONDUCTOR

POSITION OF VERTICES AND CORRESPONDING WEDGE ANGLES

X	Y	Z	ANGLES	EDGE NUMBER
999.0000	-999.0000	1.0000	90.00	1
999.0000	0.0	1.0000	90.00	2
-999.0000	0.0	1.0000	90.00	3
-999.0000	-999.0000	1.0000	90.00	4
999.0000	-999.0000	1.0000		

DIFFRACTION IS CONSIDERED FROM THE FOLLOWING EDGES

2

- - - - SEGMENTATION DATA - - - -

I+ AND I- INDICATE THE SEGMENTS BEFORE AND AFTER I

SEG.	COORDINATES OF SEG. CENTER			SEG.	ORIENTATION ANGLES		CONNECTION DATA			TAG	- - - - CURRENT - - - -	
NO.	X	Y	Z	LENGTH	ALPHA	BETA	I-	I	I+	NO.	REAL	IMAG.
1	0.0	-10.00000	1.00100	0.00200	90.000	0.0	0	0	0	0	0.1000E+01	0.0

PATTERN OF TOTAL FIELD

THETA	PHI	NORMALIZED POWER GAIN E-THETA	F-PHI	TOTAL
90.00	270.00	-2.2379	-328.2026	-2.2379
85.00	270.00	-2.2463	-198.1148	-2.2463
80.00	270.00	-2.3223	-191.4363	-2.3223
75.00	270.00	-2.6188	-187.2132	-2.6188
70.00	270.00	-3.0797	-185.5648	-3.0797
65.00	270.00	-3.1375	-184.9494	-3.1375
60.00	270.00	-3.5597	-181.4945	-3.5597
55.00	270.00	-4.1760	-182.2966	-4.1760
50.00	270.00	-4.6168	-179.2915	-4.6168
45.00	270.00	-5.2774	-180.5804	-5.2774
40.00	270.00	-6.4776	-178.3432	-6.4776
35.00	270.00	-6.9675	-177.3142	-6.9675
30.00	270.00	-8.0959	-178.5508	-8.0959
25.00	270.00	-10.1225	-178.3347	-10.1225
20.00	270.00	-12.2927	-176.5721	-12.2927
15.00	270.00	-14.2536	-175.5479	-14.2536
10.00	270.00	-16.7005	-175.5509	-16.7005
5.00	270.00	-21.1554	-176.3383	-21.1554
0.0	90.00	-33.0921	-161.8432	-33.0921
5.00	90.00	-22.9379	-165.9019	-22.9378
10.00	90.00	-18.0954	-165.5876	-18.0954
15.00	90.00	-14.9491	-163.6509	-14.9481
20.00	90.00	-12.8284	-162.3796	-12.8284
25.00	90.00	-10.8319	-157.2800	-10.8319
30.00	90.00	-8.1024	-154.6875	-8.1024
35.00	90.00	-5.7324	-153.5335	-5.7324
40.00	90.00	-5.6719	-153.2257	-5.6719
45.00	90.00	-7.1703	-152.9727	-7.1703
50.00	90.00	-3.9392	-154.3012	-3.9392
55.00	90.00	-3.8637	-159.9791	-3.8637
60.00	90.00	-3.8057	-172.5288	-3.8057
65.00	90.00	-3.1617	-158.6953	-3.1617
70.00	90.00	-3.4508	-154.4868	-3.4508
75.00	90.00	0.0	-152.9862	0.0
80.00	90.00	-4.1244	-154.8378	-4.1244
85.00	90.00	-5.4239	-162.5244	-5.4239
90.00	90.00	-2.2375	-246.5166	-2.2375

TOTAL FIELD AT R = 0.1000E+06 METERS

THETA	PHI	THETA COMPONENT AMPLITUDE	THETA COMPONENT PHASE	PHI COMPONENT AMPLITUDE	PHI COMPONENT PHASE
90.00	270.00	0.764383E-05	89.23	0.384639E-21	180.00
85.00	270.00	0.763644E-05	107.11	0.122876E-14	11.65
80.00	270.00	0.756993E-05	98.01	0.265986E-14	1.35
75.00	270.00	0.731583E-05	61.64	0.431066E-14	-30.79
70.00	270.00	0.693781E-05	-3.81	0.521152E-14	-87.37
65.00	270.00	0.689178E-05	-96.31	0.559414E-14	171.92
60.00	270.00	0.656475E-05	148.99	0.832693E-14	56.33
55.00	270.00	0.611515E-05	4.11	0.759234E-14	-81.33
50.00	270.00	0.581253E-05	-159.33	0.107307E-13	107.74
45.00	270.00	0.538684E-05	8.53	0.925090E-14	-82.64
40.00	270.00	0.469167E-05	160.46	0.119687E-13	76.59
35.00	270.00	0.443435E-05	-68.56	0.134739E-13	-164.70
30.00	270.00	0.389414E-05	39.97	0.116858E-13	-54.43
25.00	270.00	0.308377E-05	135.03	0.119804E-13	53.17
20.00	270.00	0.240199E-05	-139.20	0.146756E-13	137.32
15.00	270.00	0.191657E-05	-64.93	0.165125E-13	-158.77
10.00	270.00	0.144603E-05	-4.28	0.164894E-13	-125.59
5.00	270.00	0.865833E-06	42.69	0.150760E-13	-57.06
0.0	90.00	0.219083E-06	-135.00	0.799911E-13	-142.55
5.00	90.00	0.705202E-06	117.66	0.507115E-13	50.71
10.00	90.00	0.123151E-05	170.62	0.519779E-13	56.15
15.00	90.00	0.176928E-05	-138.85	0.649620E-13	74.37
20.00	90.00	0.225832E-05	-83.91	0.946723E-13	95.08
25.00	90.00	0.284195E-05	-19.47	0.138422E-12	112.31
30.00	90.00	0.389120E-05	50.93	0.182318E-12	125.63
35.00	90.00	0.511192E-05	121.71	0.208224E-12	134.17
40.00	90.00	0.514766E-05	-158.52	0.215734E-12	135.86
45.00	90.00	0.433203E-05	-41.00	0.222109E-12	136.16
50.00	90.00	0.628416E-05	90.75	0.190607E-12	144.50
55.00	90.00	0.633901E-05	-137.72	0.991402E-13	151.86
60.00	90.00	0.638144E-05	32.00	0.233757E-13	-152.93
65.00	90.00	0.687259E-05	-133.72	0.114931E-12	-49.93
70.00	90.00	0.664763E-05	55.77	0.186578E-12	-41.67
75.00	90.00	0.989021E-05	-49.01	0.221765E-12	-34.18
80.00	90.00	0.615154E-05	-127.19	0.179191E-12	-28.08
85.00	90.00	0.529676E-05	120.40	0.739567E-13	-16.62
90.00	90.00	0.764420E-05	89.23	0.467060E-17	0.0

C. 3/4λ Vertical Monopole Over a Dielectric

The geometry of this problem is indicated in Figure 12. The current on the monopole is assumed to be sinusoidal so that AMP is not needed to determine the currents. The monopole is divided into 8 current segments. The monopole is over a dielectric half space with $\varepsilon_r = 4$, and no diffracting plate is present in the original problem. However, to fulfill the program logic requirements that a plate with at least one diffracting edge must be included in each problem a very small plate far from the monopole is included, and this plate is further constrained to have only one diffracting edge so that its effect on the pattern is negligible. The results from the GTD-AMP code are compared with results from Collin and Zucker [4] in Figure 12.

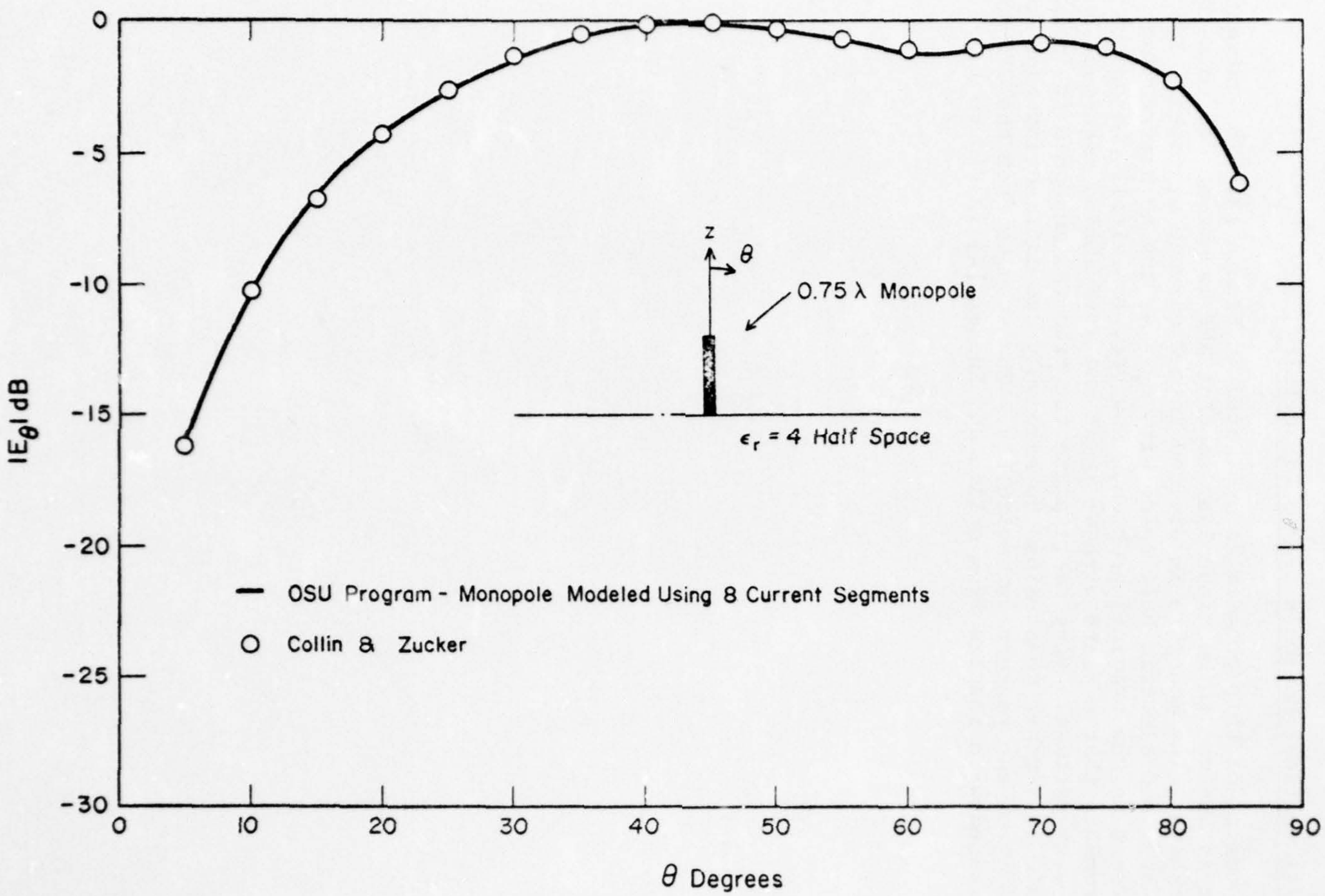

Figure 12. Calculated radiation patterns for a 3/4λ monopole over a dielectric half space.

Case C   Input

```
.*TEST #4
SECTION         1
NO. EDGES       4     1
DIFF. EDGE      1
VERTEX     99.9997    99.9997    100.
VERTEX     100.0003   99.9997    100.
VERTEX     100.0003   100.0003   100.
VERTEX     99.9997    100.0003   100.
GROUND PL.      1   4.0000E+00   0.0000E+00
SECTION         2
# SEGMENTS      8
0.0        0.0        .05        .1         90.        0.0
0.0        0.0        .15        .1         90.        0.0
0.0        0.0        .25        .1         90.        0.0
0.0        0.0        .35        .1         90.        0.0
0.0        0.0        .45        .1         90.        0.0
0.0        0.0        .55        .1         90.        0.0
0.0        0.0        .65        .1         90.        0.0
0.0        0.0        .725       .05        90.        0.0
 -0.9511E+00   0.0000E+00
 -0.5878E+00   0.0000E+00
  0.0000E+00   0.0000E+00
  0.5878E+00   0.0000E+00
  0.9511E+00   0.0000E+00
  0.9511E+00   0.0000E+00
  0.5878E+00   0.0000E+00
  0.1564E+00   0.0000E+00
SECTION         3
PATTERN    90.        180.       5.         270.       0.0        +1.0000E+05
SECTION         4
OUTPUT          0    1    2    0    0    0    0    00.0
```

Case C   Output

*TEST #4

```
******************************
*            UNITS           *
*            -----           *
*                            *
*        LENGTH : METERS     *
*         PHASE : DEGREES    *
* ELECTRIC FIELD : VOLTS/METER *
*       PATTERN : DB         *
*     FREQUENCY =   0.3000GHZ *
*    WAVELENGTH =   1.0000 M *
******************************
```

HALF SPACE BELOW X-Y PLANE :

RELATIVE PERMITTIVITY : 0.4000E+01
CONDUCTIVITY : 0.0

POSITION OF VERTICES AND CORRESPONDING WEDGE ANGLES

X	Y	Z	ANGLES	EDGE NUMBER
99.9997	99.9997	100.0000	0.0	1
100.0003	99.9997	100.0000	0.0	2
100.0003	100.0003	100.0000	0.0	3
99.9997	100.0003	100.0000	0.0	4
99.9997	99.9997	100.0000		

DIFFRACTION IS CONSIDERED FROM THE FOLLOWING EDGES

1

- - - - SEGMENTATION DATA - - - -

I+ AND I- INDICATE THE SEGMENTS BEFORE AND AFTER I

SEG. NO.	COORDINATES OF SEG. CENTER X	Y	Z	SEG. LENGTH	ORIENTATION ANGLES ALPHA	BETA	CONNECTION DATA I-	I	I+	TAG NO.	- - - - CURRENT - - - - REAL	IMAG.
1	0.0	0.0	0.05000	0.10000	90.000	0.0	0	0	0	0	-0.9511E+00	0.0
2	0.0	0.0	0.15000	0.10000	90.000	0.0	0	0	0	0	-0.5878E+00	0.0
3	0.0	0.0	0.25000	0.10000	90.000	0.0	0	0	0	0	0.0	0.0
4	0.0	0.0	0.35000	0.10000	90.000	0.0	0	0	0	0	0.5878E+00	0.0
5	0.0	0.0	0.45000	0.10000	90.000	0.0	0	0	0	0	0.9511E+00	0.0
6	0.0	0.0	0.55000	0.10000	90.000	0.0	0	0	0	0	0.9511E+00	0.0
7	0.0	0.0	0.65000	0.10000	90.000	0.0	0	0	0	0	0.5878E+00	0.0
8	0.0	0.0	0.72500	0.05000	0.000	0.0	0	0	0	0	0.1564E+00	0.0

PATTERN OF TOTAL FIELD

THETA	PHI	NORMALIZED POWER GAIN E-THETA	E-PHI	TOTAL
90.00	270.00	-121.1971	-262.1694	-121.1972
85.00	270.00	-6.1465	-135.5615	-6.1465
80.00	270.00	-2.2018	-130.3299	-2.2018
75.00	270.00	-0.9677	-128.0299	-0.9677
70.00	270.00	-0.8286	-126.9070	-0.8286
65.00	270.00	-1.0236	-126.6153	-1.0236
60.00	270.00	-1.0211	-126.9068	-1.0211
55.00	270.00	-0.6850	-127.6309	-0.6850
50.00	270.00	-0.2535	-128.6451	-0.2535
45.00	270.00	0.0	-129.7680	0.0
40.00	270.00	-0.0695	-130.7611	-0.0695
35.00	270.00	-0.5130	-131.3915	-0.5130
30.00	270.00	-1.3480	-131.5738	-1.3480
25.00	270.00	-2.5993	-131.4189	-2.5993
20.00	270.00	-4.3338	-131.1117	-4.3338
15.00	270.00	-6.7184	-130.7935	-6.7184
10.00	270.00	-10.1830	-130.5391	-10.1830
5.00	270.00	-16.1793	-130.3798	-16.1793
0.0	90.00	-130.9125	-130.3259	-127.5990

TOTAL FIELD AT R = 0.1000E+06 METERS

THETA	PHI	THETA COMPONENT AMPLITUDE	THETA COMPONENT PHASE	PHI COMPONENT AMPLITUDE	PHI COMPONENT PHASE
90.00	270.00	0.465661E-09	90.00	0.416334E-16	-90.00
85.00	270.00	0.263391E-03	159.11	0.890938E-10	-5.45
80.00	270.00	0.414795E-03	163.07	0.161409E-09	-4.35
75.00	270.00	0.478121E-03	170.25	0.212533E-09	-2.46
70.00	270.00	0.495839E-03	-178.71	0.241309E-09	0.32
65.00	270.00	0.475053E-03	-163.80	0.240550E-09	4.15
60.00	270.00	0.475191E-03	-146.84	0.241316E-09	9.28
55.00	270.00	0.49394[illegible]E-03	-131.01	0.222013E-09	16.04
50.00	270.00	0.519096E-03	-118.34	0.197546E-09	24.86
45.00	270.00	0.534470E-03	-108.91	0.17358[illegible]E-09	36.11
40.00	270.00	0.530211E-03	-101.98	0.154835E-09	49.68
35.00	270.00	0.523817E-03	-96.80	0.143995E-09	64.51
30.00	270.00	0.457638E-03	-92.86	0.141004E-09	78.71
25.00	270.00	0.396240E-03	-89.82	0.143543E-09	90.71
20.00	270.00	0.324514E-03	-87.49	0.14871[illegible]E-09	99.93
15.00	270.00	0.246607E-03	-85.75	0.154259E-09	106.54
10.00	270.00	0.165490E-03	-84.54	0.158843E-09	110.93
5.00	270.00	0.829774E-04	-83.82	0.161784E-09	113.42
0.0	90.00	0.152160E-09	-102.68	0.162790E-09	-65.77

D. <u>Three Element Yagi Over a Finite Ground Plane -- AMP Interface</u>

In this section we are concerned with finding the pattern of a three-element Yagi antenna in the presence of a 13λ square conducting plate. The dimensions of the Yagi are shown in Figure 13.

In order to find the currents on the Yagi elements, the AMP program is used and the currents are found with the Yagi located above an infinite ground plane. As discussed previously, these currents will be affected very little by the presence of the plate edges provided the edges are at least $\lambda/4$ away, as is the case here. The AMP program output [5] is listed on the following pages.

The currents from the AMP program output were input to the GTD-AMP code via the input cards listed following the AMP output listing. Two different geometries were included: 1) Yagi over 13λ square plate; 2) Yagi over infinite groundplane. Note that the Yagi currents, since they are the same for both geometries, need not be repeated. The results from the GTD-AMP code are listed and are compared with one another and with the pattern calculated by AMP in Figure 13. Measured data for this problem is given by Kraus [6], and shows good agreement with the calculated values in Figure 13.

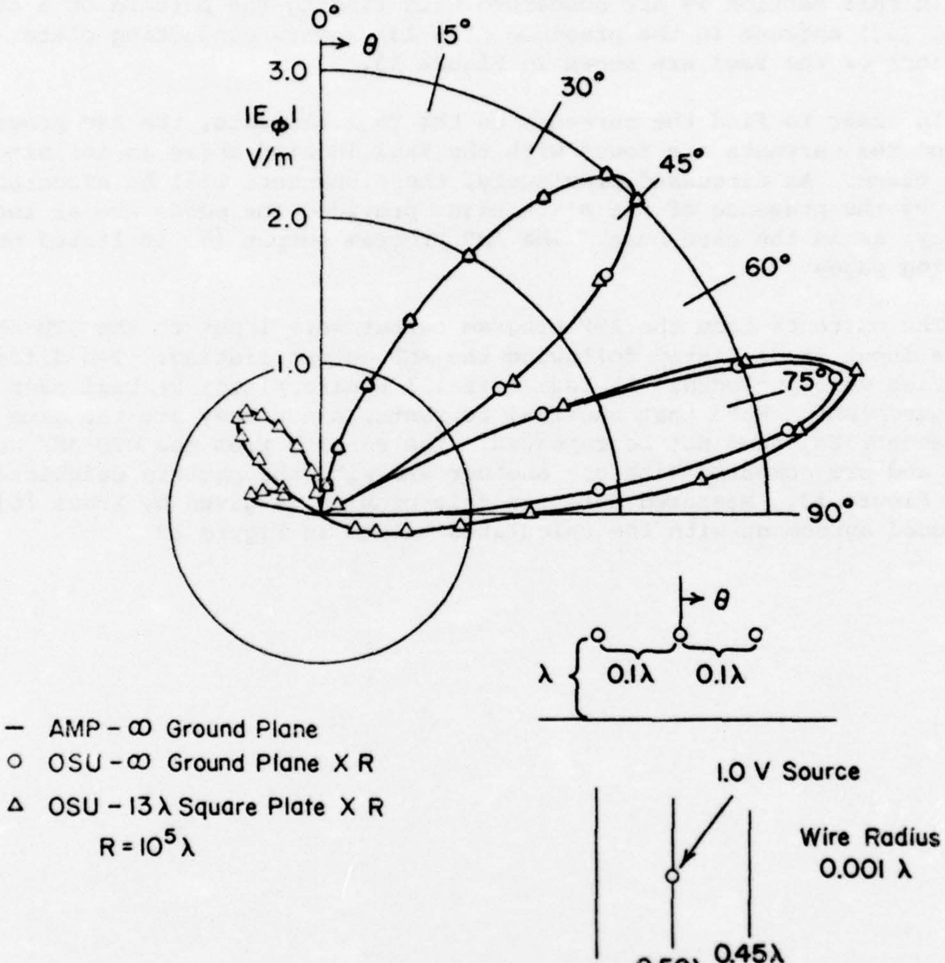

Figure 13. Calculated patterns for a 3 element beam antenna over a ground plane and over a finite plate.

Case D   AMP Output

****

ANTENNA MODELING PROGRAM

****

- - - - COMMENTS - - - -

THIS IS A 3 ELEMENT YAGI ABOVE INFINITE GROUND PLANE +0.001 RADIUS

- - - STRUCTURE SPECIFICATION - - -

COORDINATES MUST BE INPUT IN
METERS OR BE SCALED TO METERS
BEFORE STRUCTURE INPUT IS ENDED

WIRE NO.	X1	Y1	Z1	X2	Y2	Z2	RADIUS	NO. OF SEG.	FIRST SEG.	LAST SEG.	TAG NO.
1	-0.29000	-0.10000	1.00000	0.29000	-0.10000	1.00000	0.00100	11	1	11	1
2	-0.25000	0.	1.00000	0.25000	0.	1.00000	0.00100	9	12	20	2
3	-0.22500	0.10000	1.00000	0.22500	0.10000	1.00000	0.00100	9	21	29	3

GROUND PLANE SPECIFIED.

WHERE WIRE ENDS TOUCH GROUND, CURRENT WILL BE INTERPOLATED TO IMAGE IN GROUND PLANE.

TOTAL SEGMENTS USED= 29   NO. SEG. IN A SYMMETRIC CELL= 29   SYMMETRY FLAG= 0

- - - - SEGMENTATION DATA - - - -

COORDINATES IN METERS

I+ AND I- INDICATE THE SEGMENTS BEFORE AND AFTER I

SEG. NO.	COORDINATES OF SEG. CENTER X	Y	Z	SEG. LENGTH	ORIENTATION ANGLES ALPHA	BETA	WIRE RADIUS	CONNECTION DATA I-	I	I+	TAG NO.
1	-0.26364	-0.10000	1.00000	0.05273	0.	0.	0.00100	0	1	2	1
2	-0.21091	-0.10000	1.00000	0.05273	0.	0.	0.00100	1	2	3	1
3	-0.15818	-0.10000	1.00000	0.05273	0.	0.	0.00100	2	3	4	1
4	-0.10545	-0.10000	1.00000	0.05273	0.	0.	0.00100	3	4	5	1
5	-0.05273	-0.10000	1.00000	0.05273	0.	0.	0.00100	4	5	6	1
6	0.00000	-0.10000	1.00000	0.05273	0.	0.	0.00100	5	6	7	1
7	0.05273	-0.10000	1.00000	0.05273	0.	0.	0.00100	6	7	8	1
8	0.10545	-0.10000	1.00000	0.05273	0.	0.	0.00100	7	8	9	1
9	0.15818	-0.10000	1.00000	0.05273	0.	0.	0.00100	8	9	10	1
10	0.21091	-0.10000	1.00000	0.05273	0.	0.	0.00100	9	10	11	1
11	0.26364	-0.10000	1.00000	0.05273	0.	0.	0.00100	10	11	0	1
12	-0.22222	0.	1.00000	0.05556	0.	0.	0.00100	0	12	13	2
13	-0.16667	0.	1.00000	0.05556	0.	0.	0.00100	12	13	14	2
14	-0.11111	0.	1.00000	0.05556	0.	0.	0.00100	13	14	15	2

```
 15  -0.05556  0.              1.00000  0.05556   0.          0.          0.00100   14   15   16      2
 16   0.00000  0.              1.00000  0.05556   0.          0.          0.00100   15   16   17      2
 17   0.05556  0.              1.00000  0.05556   0.          0.          0.00100   16   17   18      2
 18   0.11111  0.              1.00000  0.05556   0.          0.          0.00100   17   18   19      2
 19   0.16667  0.              1.00000  0.05556   0.          0.          0.00100   18   19   20      2
 20   0.22222  0.              1.00000  0.05556   0.          0.          0.00100   19   20    0      2
 21  -0.20000  0.10000         1.00000  0.05000   0.          0.          0.00100    0   21   22      3
 22  -0.15000  0.10000         1.00000  0.05000   0.          0.          0.00100   21   22   23      3
 23  -0.10000  0.10000         1.00000  0.05000   0.          0.          0.00100   22   23   24      3
 24  -0.05000  0.10000         1.00000  0.05000   0.          0.          0.00100   23   24   25      3
 25   0.00000  0.10000         1.00000  0.05000   0.          0.          0.00100   24   25   26      3
 26   0.05000  0.10000         1.00000  0.05000   0.          0.          0.00100   25   26   27      3
 27   0.10000  0.10000         1.00000  0.05000   0.          0.          0.00100   26   27   28      3
 28   0.15000  0.10000         1.00000  0.05000   0.          0.          0.00100   27   28   29      3
 29   0.20000  0.10000         1.00000  0.05000   0.          0.          0.00100   28   29    0      3


***** DATA CARD NO.  1  FR  0   0   0    0 0.30000E 03 0.           0.           0.       0.       0.
***** DATA CARD NO.  2  GN  1   0   0    0 0.          0.           0.           0.       0.       0.
***** DATA CARD NO.  3  EX  0   2   5    1 0.10000E 01 0.           0.           0.       0.       0.
***** DATA CARD NO.  4  RP  0  36   1 1410 0.90000E 02 0.90000E 02 -0.50000E 01  0.       0.       0.


                    - - - - - - FREQUENCY - - - - - -

                     FREQUENCY= 0.3000E 03 MHZ
                     WAVELENGTH= 0.1000E 01 METERS


                    - - - STRUCTURE IMPEDANCE LOADING - - -

                     THIS STRUCTURE IS NOT LOADED


                    - - - ANTENNA ENVIRONMENT - - -
                          PERFECT GROUND


                    - - - MATRIX TIMING - - -

           FILL=    0.    SEC.,  FACTOR=    0.    SEC.


                              - - - ANTENNA INPUT PARAMETERS - - -
 TAG  SEG.     VOLTAGE (VOLTS)            CURRENT (AMPS)             IMPEDANCE (OHMS)           ADMITTANCE (MHOS)          POWER
 NO.  NO.     REAL         IMAG.          REAL         IMAG.         REAL         IMAG.         REAL         IMAG.         (WATTS)
  2    16  0.10000E 01  0.             0.23677E-01 -0.75962E-02  0.38032E 02  0.12100E 02  0.23677E-01 -0.75962E-02  0.11938E-01


                    - - - CURRENTS AND LOCATION - - -

                     DISTANCES IN WAVELENGTHS

 SEG.  TAG    COORD. OF SEG. CENTER      SEG.          - - - CURRENT (AMPS) - - -
 NO.   NO.     X        Y        Z       LENGTH    REAL       IMAG.       MAG.       PHASE
```

1	1	-0.2636	0.1000	1.0000	0.05273	0.2732E-03	0.6394E-03	0.6953E-03	66.866
2	1	-0.2109	0.1000	1.0000	0.05273	0.5562E-03	0.1796E-02	0.1880E-02	72.795
3	1	-0.1582	0.1000	1.0000	0.05273	0.6423E-03	0.2878E-02	0.2949E-02	77.420
4	1	-0.1055	0.1000	1.0000	0.05273	0.6392E-03	0.3760E-02	0.3814E-02	80.351
5	1	-0.0527	0.1000	1.0000	0.05273	0.6149E-03	0.4329E-02	0.4372E-02	81.915
6	1	0.0000	0.1000	1.0000	0.05273	0.6034E-03	0.4524E-02	0.4564E-02	82.402
7	1	0.0527	0.1000	1.0000	0.05273	0.6149E-03	0.4329E-02	0.4372E-02	81.915
8	1	0.1055	0.1000	1.0000	0.05273	0.6392E-03	0.3760E-02	0.3814E-02	80.351
9	1	0.1582	0.1000	1.0000	0.05273	0.6423E-03	0.2878E-02	0.2949E-02	77.420
10	1	0.2109	0.1000	1.0000	0.05273	0.5562E-03	0.1796E-02	0.1880E-02	72.795
11	1	0.2636	0.1000	1.0000	0.05273	0.2732E-03	0.6394E-03	0.6953E-03	66.866
12	2	-0.2222	0.	1.0000	0.05556	0.4788E-02	-0.1979E-02	0.5180E-02	-22.455
13	2	-0.1667	0.	1.0000	0.05556	0.1248E-01	-0.4859E-02	0.1339E-01	-21.269
14	2	-0.1111	0.	1.0000	0.05556	0.1857E-01	-0.6811E-02	0.1978E-01	-20.145
15	2	-0.0556	0.	1.0000	0.05556	0.2251E-01	-0.7750E-02	0.2381E-01	-18.999
16	2	0.0000	0.	1.0000	0.05556	0.2388E-01	-0.7596E-02	0.2506E-01	-17.648
17	2	0.0556	0.	1.0000	0.05556	0.2251E-01	-0.7750E-02	0.2381E-01	-18.999
18	2	0.1111	0.	1.0000	0.05556	0.1857E-01	-0.6811E-02	0.1978E-01	-20.145
19	2	0.1667	0.	1.0000	0.05556	0.1248E-01	-0.4859E-02	0.1339E-01	-21.269
20	2	0.2222	0.	1.0000	0.05556	0.4788E-02	-0.1979E-02	0.5180E-02	-22.455
21	3	-0.2000	0.1000	1.0000	0.05000	-0.3706E-02	-0.2102E-02	0.4263E-02	-150.454
22	3	-0.1500	0.1000	1.0000	0.05000	-0.9474E-02	-0.5261E-02	0.1084E-01	-150.957
23	3	-0.1000	0.1000	1.0000	0.05000	-0.1389E-01	-0.7625E-02	0.1585E-01	-151.237
24	3	-0.0500	0.1000	1.0000	0.05000	-0.1670E-01	-0.9118E-02	0.1903E-01	-151.373
25	3	0.0000	0.1000	1.0000	0.05000	-0.1767E-01	-0.9630E-02	0.2012E-01	-151.410
26	3	0.0500	0.1000	1.0000	0.05000	-0.1670E-01	-0.9118E-02	0.1903E-01	-151.373
27	3	0.1000	0.1000	1.0000	0.05000	-0.1389E-01	-0.7625E-02	0.1585E-01	-151.237
28	3	0.1500	0.1000	1.0000	0.05000	-0.9474E-02	-0.5261E-02	0.1084E-01	-150.957
29	3	0.2000	0.1000	1.0000	0.05000	-0.3706E-02	-0.2102E-02	0.4263E-02	-150.454

- - - POWER BUDGET - - -

INPUT POWER = 0.1194E-01 WATTS
RADIATED POWER= 0.1194E-01 WATTS
STRUCTURE LOSS= 0. WATTS
NETWORK LOSS = 0. WATTS
EFFICIENCY = 100.00 PERCENT

- - - RADIATION PATTERNS - - -

- - ANGLES - -		- DIRECTIVE GAINS -			- - - POLARIZATION - - -			- - - E(THETA) - - -		- - - E(PHI) - - -	
THETA DEGREES	PHI DEGREES	VERT. DB	HOR. DB	TOTAL DB	AXIAL RATIO	TILT DEG.	SENSE	MAGNITUDE VOLTS/M	PHASE DEGREES	MAGNITUDE VOLTS/M	PHASE DEGREES
90.00	90.00	-199.99	-127.06	-127.06	0.	90.00	LINEAR	0.	-45.00	0.37511E-06	135.00
85.00	90.00	-171.29	6.88	6.88	0.	-90.00	LINEAR	0.25870E-08	-47.53	0.18676E 01	132.47
80.00	90.00	-159.72	11.46	11.46	0.	-90.00	LINEAR	0.87373E-08	-47.62	0.31649E 01	132.38
75.00	90.00	-155.31	12.41	12.41	0.	-90.00	LINEAR	0.14525E-07	-47.78	0.35299E 01	132.22
70.00	90.00	-154.52	10.77	10.77	0.	-90.00	LINEAR	0.15894E-07	-48.01	0.29230E 01	131.99
65.00	90.00	-157.90	5.56	5.56	0.	-90.00	LINEAR	0.10778E-07	-48.29	0.16041E 01	131.71
60.00	90.00	-199.99	-155.65	-155.65	0.	-90.00	LINEAR	0.11097E-15	0.	0.13960E-07	180.00
55.00	90.00	-156.04	4.76	4.76	0.	-90.00	LINEAR	0.13347E-07	130.97	0.14637E 01	-49.03
50.00	90.00	-150.43	9.38	9.38	0.	-90.00	LINEAR	0.25472E-07	130.53	0.24025E 01	-49.47
45.00	90.00	-148.06	10.92	10.92	0.	-90.00	LINEAR	0.33430E-07	130.04	0.29746E 01	-49.96
40.00	90.00	-147.42	10.87	10.87	0.	-90.00	LINEAR	0.36023E-07	129.52	0.29576E 01	-50.48
35.00	90.00	-148.00	9.70	9.70	0.	-90.00	LINEAR	0.33679E-07	128.97	0.25861E 01	-51.03
30.00	90.00	-149.62	7.60	7.60	0.	-90.00	LINEAR	0.27945E-07	128.41	0.20296E 01	-51.59
25.00	90.00	-152.24	4.59	4.59	0.	-90.00	LINEAR	0.20681E-07	127.84	0.14353E 01	-52.16
20.00	90.00	-155.94	0.57	0.57	0.	-90.00	LINEAR	0.13503E-07	127.27	0.90382E 00	-52.73
15.00	90.00	-161.05	-4.78	-4.78	0.	-90.00	LINEAR	0.74968E-08	126.73	0.48818E 00	-53.27
10.00	90.00	-168.42	-12.32	-12.32	0.	-90.00	LINEAR	0.32040E-08	126.22	0.20489E 00	-53.78
5.00	90.00	-184.96	-24.95	-24.95	0.	-90.00	LINEAR	0.75760E-09	125.78	0.47834E-01	-54.22
0.	90.00	-199.99	-161.67	-161.67	0.	-90.00	LINEAR	0.11097E-15	180.00	0.69800E-08	0.
-5.00	90.00	-182.34	-26.34	-26.34	0.	-90.00	LINEAR	0.64613E-09	125.19	0.40796E-01	-54.81

-10.00	90.00	-171.19	-15.08	-15.08	0.	-90.00	LINEAR	0.23338E-08	125.11	0.14906E 00	-54.89
-15.00	90.00	-165.19	-8.92	-8.92	0.	-90.00	LINEAR	0.46539E-08	125.22	0.30306E 00	-54.78
-20.00	90.00	-161.45	-4.94	-4.94	0.	-90.00	LINEAR	0.71576E-08	125.57	0.47911E 00	-54.43
-25.00	90.00	-159.11	-2.29	-2.28	0.	-90.00	LINEAR	0.93721E-08	126.21	0.65044E 00	-53.79
-30.00	90.00	-157.88	-0.62	-0.62	0.	-90.00	LINEAR	0.10846E-07	127.19	0.78774E 00	-52.81
-35.00	90.00	-157.54	0.15	0.16	0.	-90.00	LINEAR	0.11228E-07	128.56	0.86213E 00	-51.44
-40.00	90.00	-158.24	0.05	0.05	0.	-90.00	LINEAR	0.10360E-07	130.37	0.85065E 00	-49.63
-45.00	90.00	-160.12	-1.13	-1.13	0.	-90.00	LINEAR	0.83465E-08	132.63	0.74262E 00	-47.37
-50.00	90.00	-163.63	-3.82	-3.82	0.	-90.00	LINEAR	0.55684E-08	135.35	0.54489E 00	-44.65
-55.00	90.00	-170.30	-9.50	-9.50	0.	-90.00	LINEAR	0.25842E-08	138.46	0.28338E 00	-41.54
-60.00	90.00	-499.79	-144.25	-144.25	0.	-90.00	LINEAR	0.41243E-15	132.27	0.51883E-07	-47.73
-65.00	90.00	-173.88	-10.43	-10.43	0.	-90.00	LINEAR	0.17110E-08	-34.71	0.25465E 00	145.29
-70.00	90.00	-171.15	-5.86	-5.86	0.	-90.00	LINEAR	0.23845E-08	-31.41	0.43117E 00	148.59
-75.00	90.00	-172.41	-4.70	-4.70	0.	-90.00	LINEAR	0.20267E-08	-29.53	0.49254E 00	151.47
-80.00	90.00	-177.16	-5.98	-5.98	0.	-90.00	LINEAR	0.11732E-08	-26.29	0.42498E 00	153.71
-85.00	90.00	-187.92	-10.76	-10.76	0.	-90.00	LINEAR	0.33980E-09	-24.87	0.24523E 00	155.13

- - - - NORMALIZED GAIN - - - -

HORIZONTAL GAIN
NORMALIZATION FACTOR = 12.41 DB

- - ANGLES - -		GAIN	- - ANGLES - -		GAIN	- - ANGLES - -		GAIN
THETA DEGREES	PHI DEGREES	DB	THETA DEGREES	PHI DEGREES	DB	THETA DEGREES	PHI DEGREES	DB
90.00	90.00	[illegible]	30.00	90.00	-4.81	-30.00	90.00	-13.03
85.00	90.00	-5.53	25.00	90.00	-7.82	-35.00	90.00	-12.24
80.00	90.00	-0.95	20.00	90.00	-11.83	-40.00	90.00	-12.36
75.00	90.00	0.	15.00	90.00	-17.18	-45.00	90.00	-13.54
70.00	90.00	-1.64	10.00	90.00	-24.72	-50.00	90.00	-16.23
65.00	90.00	-6.85	5.00	90.00	-37.36	-55.00	90.00	-21.91
60.00	90.00	-168.06	0.	90.00	-174.08	-60.00	90.00	-156.65
55.00	90.00	-7.65	-5.00	90.00	-38.74	-65.00	90.00	-22.84
50.00	90.00	-3.02	-10.00	90.00	-27.49	-70.00	90.00	-18.26
45.00	90.00	-1.49	-15.00	90.00	-21.32	-75.00	90.00	-17.11
40.00	90.00	-1.54	-20.00	90.00	-17.35	-80.00	90.00	-18.39
35.00	90.00	-2.70	-25.00	90.00	-14.69	-85.00	90.00	-23.16

***** DATA CARD NO. 5 EN 6 0 0 0 0. 0. 0. 0. 0. 0.

Case D   Input

```
*CURRENT SOURCES OVER A PLATE
.CURRENT DISTRIBUTION OBTAINED FROM AMP
SECTION        1
NO. EDGES      4     4
VERTEX     -6.5        -6.5        0.0
VERTEX      6.5        -6.5        0.0
VERTEX      6.5         6.5        0.0
VERTEX     -6.5         6.5        0.0
GROUND         0
SECTION        2
# SEGMENTS    29
-0.26364   -0.1        1.0         0.05273   0.0       0.0
-0.21091   -0.1        1.0         0.05273   0.0       0.0
-0.15818   -0.1        1.0         0.05273   0.0       0.0
-0.10545   -0.1        1.0         0.05273   0.0       0.0
-0.05273   -0.1        1.0         0.05273   0.0       0.0
 0.00000   -0.1        1.0         0.05273   0.0       0.0
 0.05273   -0.1        1.0         0.05273   0.0       0.0
 0.10545   -0.1        1.0         0.05273   0.0       0.0
 0.15818   -0.1        1.0         0.05273   0.0       0.0
 0.21091   -0.1        1.0         0.05273   0.0       0.0
 0.26364   -0.1        1.0         0.05273   0.0       0.0
-0.22222    0.0        1.0         0.05556   0.0       0.0
-0.16667    0.0        1.0         0.05556   0.0       0.0
-0.11111    0.0        1.0         0.05556   0.0       0.0
-0.05556    0.0        1.0         0.05556   0.0       0.0
 0.00000    0.0        1.0         0.05556   0.0       0.0
 0.05556    0.0        1.0         0.05556   0.0       0.0
 0.11111    0.0        1.0         0.05556   0.0       0.0
 0.16667    0.0        1.0         0.05556   0.0       0.0
 0.22222    0.0        1.0         0.05556   0.0       0.0
-0.20000    0.1        1.0         0.05000   0.0       0.0
-0.15000    0.1        1.0         0.05000   0.0       0.0
-0.10000    0.1        1.0         0.05000   0.0       0.0
-0.05000    0.1        1.0         0.05000   0.0       0.0
 0.00000    0.1        1.0         0.05000   0.0       0.0
 0.05000    0.1        1.0         0.05000   0.0       0.0
 0.10000    0.1        1.0         0.05000   0.0       0.0
 0.15000    0.1        1.0         0.05000   0.0       0.0
 0.20000    0.1        1.0         0.05000   0.0       0.0
 +0.2732E-03 +0.6394E-03
 +0.5562E-03 +0.1796E-02
 +0.6423E-03 +0.2878E-02
 +0.6392E-03 +0.3760E-02
 +0.6149E-03 +0.4329E-02
 +0.6034E-03 +0.4524E-02
 +0.6149E-03 +0.4329E-02
 +0.6392E-03 +0.3760E-02
 +0.6423E-03 +0.2878E-02
 +0.5562E-03 +0.1796E-02
 +0.2732E-03 +0.6394E-03
 +0.4788E-02 -0.1979E-02
 +0.1248E-01 -0.4859E-02
 +0.1857E-01 -0.6811E-02
 +0.2251E-01 -0.7750E-02
 +0.2388E-01 -0.7596E-02
 +0.2251E-01 -0.7750E-02
 +0.1857E-01 -0.6811E-02
 +0.1248E-01 -0.4859E-02
 +0.4788E-02 -0.1979E-02
 -0.3708E-02 -0.2102E-02
 -0.9474E-02 -0.5261E-02
```

```
 -0.1389E-01 -0.7625E-02
  -0.1670E-01 -0.9118E-02
  -0.1767E-01 -0.9630E-02
  -0.1670E-01 -0.9118E-02
  -0.1389E-01 -0.7625E-02
  -0.9474E-02 -0.5261E-02
  -0.3708E-02 -0.2102E-02
SECTION         3
PATTERN    0.        360.       5.         90.        0.0       +1.0000E+05
SECTION         4
OUTPUT          0    1    2    0    0    0    0    00.0
*SOURCE OVER PERFECT CONDUCTOR GROUND PLANE
.CURRENT DISTRIBUTION OBTAINED FROM AMP
SECTION         1
NO. EDGES       4    1
DIFF. EDGE      2
VERTEX     99.9997     99.9997     100.
VERTEX     100.0003    99.9997     100.
VERTEX     100.0003    100.0003    100.
VERTEX     99.9997     100.0003    100.
GROUND          1  0.0000E+00  0.0000E+00
SECTION         3    1
PATTERN    90.       270.       5.         90.        0.0       +1.0000E+05
```

Case D Output

CURRENT SOURCES OVER A PLATE
CURRENT DISTRIBUTION OBTAINED FROM AMP

UNITS	
LENGTH :	METERS
PHASE :	DEGREES
ELECTRIC FIELD :	VOLTS/METER
PATTERN :	DB
FREQUENCY =	0.3000GHZ
WAVELENGTH =	1.0000 M

POSITION OF VERTICES AND CORRESPONDING WEDGE ANGLES

X	Y	Z	ANGLES	EDGE NUMBER
-6.5000	-6.5000	0.0		
6.5000	-6.5000	0.0	0.0	1
6.5000	6.5000	0.0	0.0	2
-6.5000	6.5000	0.0	0.0	3
-6.5000	-6.5000	0.0	0.0	4

- - - - SEGMENTATION DATA - - - -

I+ AND I- INDICATE THE SEGMENTS BEFORE AND AFTER I

SEG. NO.	COORDINATES OF SEG. CENTER X	Y	Z	SEG. LENGTH	ORIENTATION ANGLES ALPHA	BETA	CONNECTION DATA I-	I	I+	TAG NO.	CURRENT REAL	IMAG.
1	-0.26364	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.2732E-03	0.6394E-03
2	-0.21071	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.5562E-03	0.1796E-02

3	-0.15819	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6423E-03	0.2878E-02
4	-0.10545	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6392E-03	0.3760E-02
5	-0.05273	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6149E-03	0.4329E-02
6	0.0	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6034E-03	0.4524E-02
7	0.05273	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6149E-03	0.4329E-02
8	0.10545	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6392E-03	0.3760E-02
9	0.15819	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6423E-03	0.2878E-02
10	0.21091	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.5562E-03	0.1796E-02
11	0.26364	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.2732E-03	0.6394E-03
12	-0.22222	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.4788E-02	-0.1979E-02
13	-0.16667	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.1248E-01	-0.4859E-02
14	-0.11111	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.1857E-01	-0.6811E-02
15	-0.05556	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.2251E-01	-0.7750E-02
16	0.0	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.2388E-01	-0.7596E-02
17	0.05556	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.2251E-01	-0.7750E-02
18	0.11111	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.1857E-01	-0.6811E-02
19	0.16667	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.1248E-01	-0.4859E-02
20	0.22222	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.4788E-02	-0.1979E-02
21	-0.20000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.3708E-02	-0.2102E-02
22	-0.15000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.9474E-02	-0.5261E-02
23	-0.10000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.1389E-01	-0.7625E-02
24	-0.05000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.1670E-01	-0.9118E-02
25	0.0	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.1767E-01	-0.9630E-02
26	0.05000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.1670E-01	-0.9118E-02
27	0.10000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.1389E-01	-0.7625E-02
28	0.15000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.9474E-02	-0.5261E-02
29	0.20000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.3708E-02	-0.2102E-02

PATTERN OF TOTAL FIELD

THETA	PHI	NORMALIZED POWER GAIN		
		E-THETA	E-PHI	TOTAL
180.00	90.00	-165.7908	-39.7534	-39.7534
175.00	90.00	-167.6434	-50.9721	-50.9721
170.00	90.00	-161.5050	-38.2595	-38.2595
165.00	90.00	-164.0192	-52.4826	-52.4826
160.00	90.00	-161.9252	-37.5084	-37.5084
155.00	90.00	-170.5620	-36.3974	-36.3975
150.00	90.00	-153.8989	-43.4472	-43.4472
145.00	90.00	-151.3046	-47.8303	-47.8303
140.00	90.00	-147.3929	-38.0138	-38.0138
135.00	90.00	-151.6373	-38.1410	-38.1410
130.00	90.00	-167.0339	-33.1332	-33.1332
125.00	90.00	-165.7765	-30.8363	-30.8863
120.00	90.00	-164.3353	-28.2527	-28.2527
115.00	90.00	-162.8881	-25.3452	-25.3452
110.00	90.00	-161.4871	-22.1061	-22.1061
105.00	90.00	-160.3641	-18.5621	-18.5621
100.00	90.00	-160.0488	-14.7803	-14.7803
95.00	90.00	-162.1751	-10.9190	-10.9190
90.00	90.00	-267.2161	-7.1957	-7.1957
85.00	90.00	-155.1365	-3.8806	-3.8806
80.00	90.00	-146.5955	-1.3269	-1.3269
75.00	90.00	-141.8020	0.0	0.0
70.00	90.00	-140.0305	-0.6496	-0.6496
65.00	90.00	-142.6145	-5.0714	-5.0714
60.00	90.00	-164.3353	-28.2527	-28.2527
55.00	90.00	-141.1970	-6.3068	-6.3068
50.00	90.00	-136.2601	-2.3595	-2.3595

45.00	90.00	-134.4566	-0.5271	-0.5271
40.00	90.00	-132.2313	-0.5444	-0.5444
35.00	90.00	-134.4406	-1.8492	-1.9492
30.00	90.00	-134.9295	-3.9846	-3.9846
25.00	90.00	-137.4852	-6.8775	-6.8775
20.00	90.00	-141.7038	-10.6470	-10.6470
15.00	90.00	-147.8927	-16.2161	-16.2161
10.00	90.00	-156.4555	-24.6022	-24.6022
5.00	90.00	-167.9759	-38.1664	-38.1664
0.0	-90.00	-161.2163	-39.7532	-39.7532
5.00	-90.00	-171.4685	-38.9120	-38.9120
10.00	-90.00	-159.6994	-27.7245	-27.7245
15.00	-90.00	-151.2078	-20.2207	-20.2207
20.00	-90.00	-146.4428	-16.2430	-16.2430
25.00	-90.00	-144.1190	-13.6867	-13.6867
30.00	-90.00	-143.0592	-12.2227	-12.2227
35.00	-90.00	-143.7917	-11.3555	-11.3555
40.00	-90.00	-144.2400	-11.3519	-11.3519
45.00	-90.00	-144.0015	-12.5303	-12.5303
50.00	-90.00	-149.3793	-15.4777	-15.4777
55.00	-90.00	-155.4783	-20.5881	-20.5881
60.00	-90.00	-182.1458	-46.0634	-46.0534
65.00	-90.00	-159.6384	-21.0953	-21.0953
70.00	-90.00	-156.7269	-17.3461	-17.3461
75.00	-90.00	-158.9177	-17.1157	-17.1157
80.00	-90.00	-165.9333	-18.6647	-18.6647
85.00	-90.00	-172.5537	-21.2977	-21.2977
90.00	-90.00	-281.4988	-24.5976	-24.5976
95.00	-90.00	-179.5144	-28.2583	-28.2583
100.00	-90.00	-177.2279	-31.9595	-31.9595
105.00	-90.00	-177.5328	-35.7310	-35.7310
110.00	-90.00	-178.8342	-39.4535	-39.4536
115.00	-90.00	-179.3316	-41.7388	-41.7389
120.00	-90.00	-182.1463	-46.0638	-46.0638
125.00	-90.00	-182.4462	-47.5561	-47.5561
130.00	-90.00	-181.6172	-47.7165	-47.7165
135.00	-90.00	-161.9095	-45.9625	-45.9625
140.00	-90.00	-151.7013	-50.4470	-50.4470
145.00	-90.00	-154.3932	-48.1262	-48.1262
150.00	-90.00	-164.0510	-47.8812	-47.8812
155.00	-90.00	-162.0879	-49.8641	-49.8641
160.00	-90.00	-169.4352	-49.1657	-49.1657
165.00	-90.00	-177.5187	-44.3421	-44.3421
170.00	-90.00	-180.4947	-43.1427	-43.1428
175.00	-90.00	-174.0833	-53.0498	-53.0493
180.00	-90.00	-166.3629	-39.7534	-39.7534

TOTAL FIELD AT R = 0.1000E+06 METERS

THETA	PHI	THETA COMPONENT AMPLITUDE	THETA COMPONENT PHASE	PHI COMPONENT AMPLITUDE	PHI COMPONENT PHASE
180.00	90.00	0.164715E-12	136.39	0.330068E-06	146.15
175.00	90.00	0.133077E-12	71.15	0.907131E-07	109.00
170.00	90.00	0.269786E-12	175.97	0.392012E-06	-175.60
165.00	90.00	0.201982E-12	128.39	0.762333E-07	-112.91
160.00	90.00	0.257644E-12	165.95	0.427418E-06	-97.67
155.00	90.00	0.950486E-13	-65.59	0.485736E-06	30.60
150.00	90.00	0.647636E-12	4.42	0.215732E-06	164.08

145.00	90.00	0.673058E-12	85.01	0.130245E-05	136.45
140.00	90.00	0.136966E-11	-137.06	0.403260E-06	-85.86
135.00	90.00	0.340243E-12	90.85	0.397396E-06	6.20
130.00	90.00	0.142751E-12	150.86	0.707315E-06	150.86
125.00	90.00	0.104937E-12	-82.27	0.916135E-06	-82.27
120.00	90.00	0.194764E-12	30.90	0.124062E-05	30.90
115.00	90.00	0.250073E-12	130.91	0.173387E-05	130.91
110.00	90.00	0.270346E-12	-143.02	0.251749E-05	-143.02
105.00	90.00	0.307655E-12	-69.89	0.378588E-05	-69.89
100.00	90.00	0.314029E-12	-9.26	0.585142E-05	-9.26
95.00	90.00	0.249755E-12	39.76	0.912687E-05	39.76
90.00	90.00	0.139737E-17	-95.84	0.140116E-04	77.96
85.00	90.00	0.561625E-12	-73.94	0.205232E-04	106.06
80.00	90.00	0.150141E-11	-55.25	0.275378E-04	124.75
75.00	90.00	0.269719E-11	-45.28	0.320829E-04	134.72
70.00	90.00	0.319701E-11	-43.21	0.297709E-04	136.79
65.00	90.00	0.237435E-11	-48.41	0.178935E-04	131.59
60.00	90.00	0.194764E-12	-149.10	0.124062E-05	30.90
55.00	90.00	0.279326E-11	129.08	0.155215E-04	-50.92
50.00	90.00	0.493481E-11	129.91	0.244512E-04	-50.09
45.00	90.00	0.607359E-11	134.33	0.301938E-04	-49.37
40.00	90.00	0.784712E-11	120.80	0.301337E-04	-50.96
35.00	90.00	0.608478E-11	132.82	0.259306E-04	-51.11
30.00	90.00	0.575177E-11	134.76	0.202788E-04	-51.99
25.00	90.00	0.428565E-11	129.33	0.145345E-04	-50.31
20.00	90.00	0.263681E-11	126.46	0.941724E-05	-54.61
15.00	90.00	0.129312E-11	125.30	0.495484E-05	-54.08
10.00	90.00	0.482496E-12	125.37	0.158870E-05	-63.99
5.00	90.00	0.128073E-12	-179.92	0.396236E-06	-50.49
0.0	-90.00	0.278905E-12	-24.29	0.330074E-06	-33.85
5.00	-90.00	0.356727E-13	99.95	0.363643E-06	117.26
10.00	-90.00	0.332122E-12	117.72	0.131840E-05	119.96
15.00	-90.00	0.882829E-12	122.09	0.312780E-05	121.81
20.00	-90.00	0.152804E-11	113.90	0.494454E-05	125.32
25.00	-90.00	0.199674E-11	121.53	0.663653E-05	126.78
30.00	-90.00	0.225325E-11	131.88	0.785490E-05	127.74
35.00	-90.00	0.164696E-11	122.91	0.867962E-05	127.67
40.00	-90.00	0.196911E-11	128.70	0.868313E-05	130.46
45.00	-90.00	0.202395E-11	127.73	0.758158E-05	133.60
50.00	-90.00	0.108983E-11	134.41	0.539993E-05	134.41
55.00	-90.00	0.539954E-12	138.21	0.299825E-05	138.21
60.00	-90.00	0.250601E-13	-128.93	0.159627E-06	-128.93
65.00	-90.00	0.375281E-12	-33.60	0.282820E-05	-33.60
70.00	-90.00	0.467653E-12	-27.12	0.435481E-05	-27.12
75.00	-90.00	0.363400E-12	-27.13	0.447185E-05	-27.13
80.00	-90.00	0.203988E-12	-34.96	0.374142E-05	-34.96
85.00	-90.00	0.756115E-13	-51.77	0.276306E-05	-51.77
90.00	-90.00	0.269976E-18	-85.40	0.188971E-05	-78.31
95.00	-90.00	0.339277E-13	64.44	0.123982E-05	-115.56
100.00	-90.00	0.441443E-13	16.22	0.809653E-06	-163.78
105.00	-90.00	0.426218E-13	-42.66	0.524475E-06	137.34
110.00	-90.00	0.360912E-13	-118.70	0.341662E-06	61.30
115.00	-90.00	0.340490E-13	159.21	0.261117E-06	-20.79
120.00	-90.00	0.250588E-13	51.07	0.159618E-06	-128.93
125.00	-90.00	0.242080E-13	-44.17	0.134421E-06	135.83
130.00	-90.00	0.260326E-13	171.56	0.131962E-06	-8.44
135.00	-90.00	0.257512E-12	-86.57	0.161491E-06	-166.53
140.00	-90.00	0.834081E-12	-84.33	0.963661E-07	147.20
145.00	-90.00	0.611799E-12	133.37	0.125882E-06	26.59
150.00	-90.00	0.201245E-12	-3.10	0.129483E-06	-94.26
155.00	-90.00	0.252277E-12	-131.71	0.103054E-06	171.93
160.00	-90.00	0.121483E-12	-162.23	0.111684E-06	116.76
165.00	-90.00	0.426909E-13	149.70	0.194611E-06	54.74
170.00	-90.00	0.302925E-13	162.35	0.223427E-06	-23.32
175.00	-90.00	0.634027E-13	165.90	0.714139E-07	-10.64
180.00	-90.00	0.145589E-12	120.76	0.330068E-06	-33.85

SOURCE OVER PERFECT CONDUCTOR GROUND PLANE
CURRENT DISTRIBUTION OBTAINED FROM AMP

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*****************************
*           UNITS           *
*           -----           *
*                           *
*       LENGTH : METERS     *
*        PHASE : DEGREES    *
* ELECTRIC FIELD : VOLTS/METER *
*      PATTERN : DB         *
*    FREQUENCY =   0.3000GHZ *
*   WAVELENGTH =   1.0000 M *
*****************************
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HALF SPACE BELOW X-Y PLANE :

X-Y PLANE IS PERFECT CONDUCTOR

POSITION OF VERTICES AND CORRESPONDING WEDGE ANGLES

X	Y	Z	ANGLES	EDGE NUMBER
99.9997	99.9997	100.0000		
			0.0	1
100.0003	99.9997	100.0000		
			0.0	2
100.0003	100.0003	100.0000		
			0.0	3
99.9997	100.0003	100.0000		
			0.0	4
99.9997	99.9997	100.0000		

DIFFRACTION IS CONSIDERED FROM THE FOLLOWING EDGES

2

- - - - SEGMENTATION DATA - - - -

I+ AND I- INDICATE THE SEGMENTS BEFORE AND AFTER I

SEG. NO.	COORDINATES OF SEG. CENTER X	Y	Z	SEG. LENGTH	ORIENTATION ANGLES ALPHA	BETA	CONNECTION DATA I-	I	I+	TAG NO.	- - - - CURRENT - - - - REAL	IMAG.
1	-0.26364	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.2732E-03	0.6394E-03
2	-0.21091	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.5562E-03	0.1796E-02
3	-0.15818	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6423E-03	0.2879E-02
4	-0.10545	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6392E-03	0.3760E-02
5	-0.05273	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6149E-03	0.4329E-02
6	0.0	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6034E-03	0.4524E-02
7	0.05273	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6149E-03	0.4329E-02
8	0.10545	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6392E-03	0.3760E-02
9	0.15818	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.6423E-03	0.2879E-02
10	0.21091	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.5562E-03	0.1796E-02
11	0.26364	-0.10000	1.00000	0.05273	0.0	0.0	0	0	0	0	0.2732E-03	0.6394E-03
12	-0.22222	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.4788E-02	-0.1979E-02
13	-0.16667	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.1248E-01	-0.4859E-02
14	-0.11111	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.1857E-01	-0.6811E-02
15	-0.05556	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.2251E-01	-0.7750E-02
16	0.0	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.2388E-01	-0.7596E-02
17	0.05556	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.2251E-01	-0.7750E-02
18	0.11111	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.1857E-01	-0.6811E-02
19	0.16667	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.1248E-01	-0.4859E-02
20	0.22222	0.0	1.00000	0.05556	0.0	0.0	0	0	0	0	0.4788E-02	-0.1979E-02
21	-0.20000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.3708E-02	-0.2102E-02
22	-0.15000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.9474E-02	-0.5261E-02
23	-0.10000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.1389E-01	-0.7625E-02
24	-0.05000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.1670E-01	-0.9118E-02
25	0.0	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.1767E-01	-0.9630E-02
26	0.05000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.1670E-01	-0.9118E-02
27	0.10000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.1389E-01	-0.7625E-02
28	0.15000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.9474E-02	-0.5261E-02
29	0.20000	0.10000	1.00000	0.05000	0.0	0.0	0	0	0	0	-0.3708E-02	-0.2102E-02

PATTERN OF TOTAL FIELD

THETA	PHI	NORMALIZED POWER GAIN E-THETA	E-PHI	TOTAL
90.00	90.00	-259.9690	-999.9900	-259.9690
85.00	90.00	-156.7856	-5.5297	-5.5297
80.00	90.00	-146.2167	-0.9482	-0.9482
75.00	90.00	-141.8020	0.0	0.0
70.00	90.00	-141.0194	-1.6385	-1.6385
65.00	90.00	-144.3934	-6.8504	-6.8504
60.00	90.00	-256.5730	-118.7257	-118.7257
55.00	90.00	-142.3355	-7.6454	-7.6454
50.00	90.00	-136.9219	-3.0212	-3.0212

45.00	90.00	-134.5575	-1.4852	-1.4852
40.00	90.00	-133.9107	-1.5338	-1.5338
35.00	90.00	-134.4946	-2.6998	-2.6998
30.00	90.00	-136.1152	-4.9038	-4.9038
25.00	90.00	-138.7290	-7.8125	-7.8125
20.00	90.00	-142.4314	-11.8292	-11.8292
15.00	90.00	-147.5416	-17.1765	-17.1765
10.00	90.00	-154.9136	-24.7187	-24.7187
5.00	90.00	-167.4488	-37.3538	-37.3538
0.0	-90.00	-260.2139	-131.3433	-131.3433
5.00	-90.00	-168.6292	-38.7342	-38.7342
10.00	-90.00	-157.6724	-27.4774	-27.4774
15.00	-90.00	-151.6758	-21.3127	-21.3127
20.00	-90.00	-147.9351	-17.3329	-17.3329
25.00	-90.00	-145.5920	-14.6755	-14.6756
30.00	-90.00	-144.3215	-13.0101	-13.0101
35.00	-90.00	-144.0158	-12.2241	-12.2241
40.00	-90.00	-144.7153	-12.3384	-12.3384
45.00	-90.00	-146.5882	-13.5159	-13.5159
50.00	-90.00	-150.1037	-16.2030	-16.2030
55.00	-90.00	-156.7701	-21.8799	-21.8799
60.00	-90.00	-263.0496	-125.7687	-125.7687
65.00	-90.00	-160.3493	-22.8063	-22.8063
70.00	-90.00	-157.6129	-18.2319	-18.2319
75.00	-90.00	-158.8781	-17.0760	-17.0760
80.00	-90.00	-163.6264	-18.3578	-18.3578
85.00	-90.00	-174.3899	-23.1338	-23.1338
90.00	-90.00	-277.6367	-999.9900	-277.6367

TOTAL FIELD AT R = 0.1000E+06 METERS

THETA	PHI	THETA COMPONENT AMPLITUDE	THETA COMPONENT PHASE	PHI COMPONENT AMPLITUDE	PHI COMPONENT PHASE
90.00	90.00	0.356871E-17	-137.53	0.0	0.0
85.00	90.00	0.514845E-12	-47.56	0.168138E-04	132.44
80.00	90.00	0.173830E-11	-47.66	0.318825E-04	132.34
75.00	90.00	0.289974E-11	-47.82	0.355601E-04	132.18
70.00	90.00	0.316221E-11	-48.05	0.294469E-04	131.95
65.00	90.00	0.214434E-11	-48.33	0.161600E-04	131.67
60.00	90.00	0.327595E-17	-9.46	0.411791E-10	133.21
55.00	90.00	0.265575E-11	130.93	0.147467E-04	-49.07
50.00	90.00	0.506837E-11	130.49	0.251131E-04	-49.51
45.00	90.00	0.665406E-11	130.00	0.299710E-04	-50.00
40.00	90.00	0.716344E-11	129.48	0.290039E-04	-50.52
35.00	90.00	0.670248E-11	128.93	0.260598E-04	-51.07
30.00	90.00	0.556163E-11	128.37	0.204537E-04	-51.63
25.00	90.00	0.411636E-11	127.79	0.144557E-04	-52.21
20.00	90.00	0.268774E-11	127.22	0.910962E-05	-52.78
15.00	90.00	0.149238E-11	126.68	0.492079E-05	-53.32
10.00	90.00	0.638677E-12	126.18	0.206552E-05	-53.32
5.00	90.00	0.150840E-12	125.73	0.482251E-06	-54.27
0.0	-90.00	0.346945E-17	0.0	0.909495E-11	-36.87
5.00	-90.00	0.126676E-12	125.14	0.411389E-06	125.14
10.00	-90.00	0.464879E-12	125.06	0.150346E-05	125.06
15.00	-90.00	0.927196E-12	125.17	0.305722E-05	125.17
20.00	-90.00	0.142627E-11	125.51	0.483414E-05	125.51
25.00	-90.00	0.186792E-11	126.15	0.656425E-05	126.15
30.00	-90.00	0.216215E-11	127.12	0.795164E-05	127.12

35.00	-90.00	0.223381E-11	128.48	0.870472E-05	128.48
40.00	-90.00	0.206630E-11	130.28	0.859095E-05	130.28
45.00	-90.00	0.166552E-11	132.53	0.750185E-05	132.53
50.00	-90.00	0.111116E-11	135.24	0.550571E-05	135.24
55.00	-90.00	0.515763E-12	138.33	0.286395E-05	138.33
60.00	-90.00	0.250308E-17	-17.65	0.183032E-10	-26.57
65.00	-90.00	0.341582E-12	-34.89	0.257423E-05	-34.88
70.00	-90.00	0.468076E-12	-31.61	0.435883E-05	-31.61
75.00	-90.00	0.404627E-12	-28.74	0.497924E-05	-28.74
80.00	-90.00	0.234229E-12	-26.52	0.429606E-05	-26.52
85.00	-90.00	0.678373E-13	-25.11	0.247897E-05	-25.11
90.00	-90.00	0.466783E-18	-114.63	0.0	0.0

APPENDIX A

MODELING THE SPECULAR REFLECTION FROM THE GROUND OR OCEAN

The reflection of EM waves from the rough ground or ocean is determined primarily by two quantities -- the constitutive parameters of the medium and the surface roughness. If the surface is relatively smooth, then the reflection will be primarily specular and can be determined quite easily from the complex permittivity of the medium. If the surface is very rough, then the reflection will be incoherent and the simplest approximation to the specular reflection is to neglect it altogether. If the surface is neither very rough nor very smooth, the problem of determining the reflection is quite involved and is beyond the scope of the present work. However, for certain cases (for example, the ocean) an effective surface impedance can be defined which will allow the calculation of an approximate average reflection from the rough surface.

A measure of surface roughness, which can be used to quantitatively determine relative roughness or smoothness, is the Rayleigh criteria:

$$R = \frac{4\pi\bar{s}\cos\theta}{\lambda}$$

where $\bar{s}$ = Standard deviation of surface irregularities
θ = Angle of incidence measured from the normal
λ = Wavelength.

For $R < 0.1$ there is a well-defined specular reflection and the reflection coefficient may be approximated using the usual plane wave reflection coefficients (in our code, this corresponds to option IGND = 1 in the Plate Data Section). For $0.1 < R < 10$ the surface roughness may not be neglected. However, if an effective surface impedance is available, it may be used to determine an approximate reflection coefficient (option IGND = 2). When $R > 10$, the surface is so rough that the specularly reflected field is negligible and can be neglected (option IGND = 0).

For making calculations for a "typical" lossy earth, the relative dielectric constant will vary from about 7 for a low conductivity earth to about 30 for a highly conductive earth, with a typical value being $\varepsilon_r = 15$. The corresponding range for the conductivity is from 1 to 30 millimho/meter [7].

For frequencies up to .5 gHZ Barrick [8] has developed an effective surface impedance which can be used to approximate the reflection from the ocean's

surface. A graph giving values of this normalized surface impedance for various states of sea roughness is shown in Figure A-1.

Finally it should be emphasized that the determination of the reflection from a statistically rough surface ($R > 0.1$) is a complex problem, so that the methods outlined here for dealing with this problem are quite simplistic and can be expected to yield only approximate results at best.

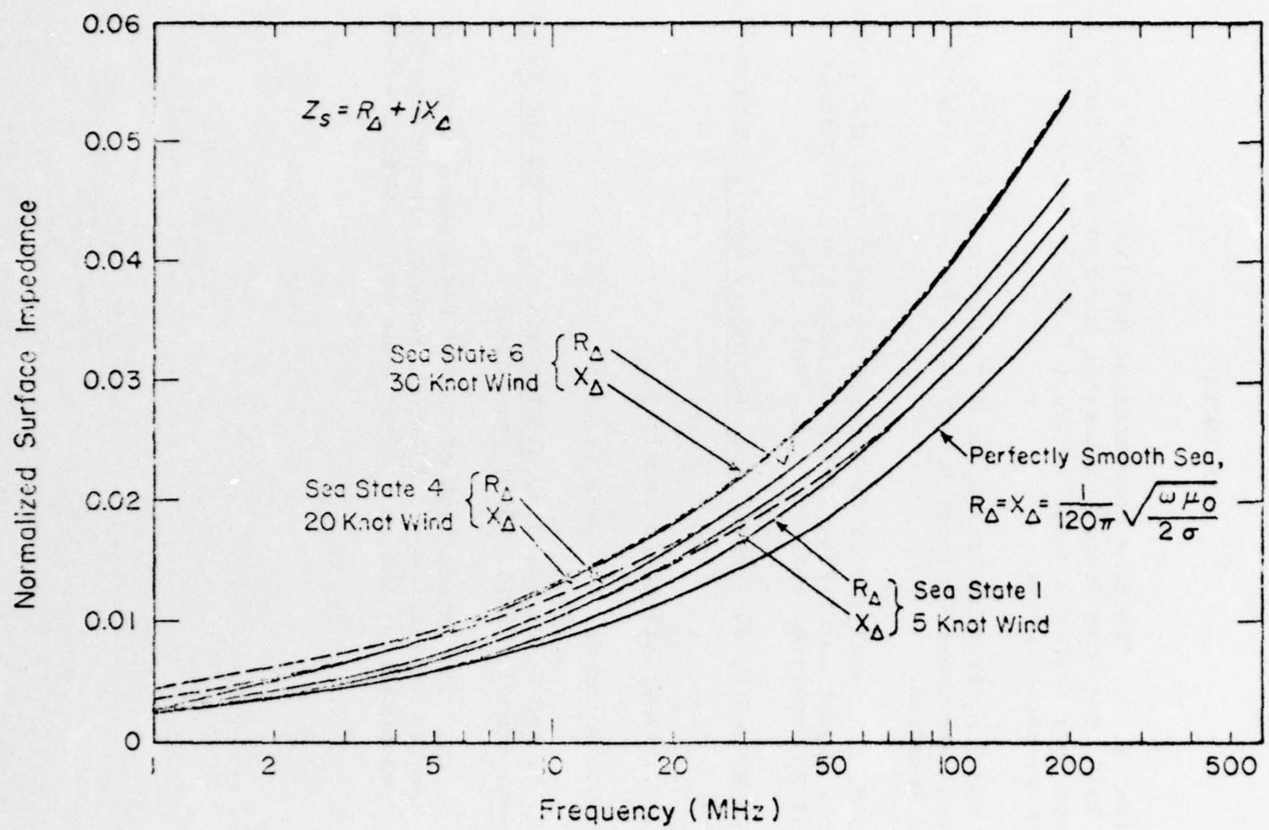

Figure A-1. Normalized effective surface impedance, z_s, vs wind speed and frequency. From Barrick [8].

REFERENCES

1. Kouyoumjian, R. G., "Antenna Mathematical Modeling (GTD)", Report 4066-1, July 1975, The Ohio State University, Department of Electrical Engineering; prepared under Contract F 30602-75-C-0051 with Rome Air Development Center.

2. "Antenna Modeling Program-User's Manual", Report MB-R-74/76, prepared by MBAssociates under Contract No. N 00014-72-C-0187 with the Office of Naval Research.

3. Burnside, W. D., "Analysis of On-Aircraft Antenna Patterns", Report 3390-1, August 1972, ElectroScience Laboratory, Department of Electrical Engineering, The Ohio State University.

4. Collin, R. E. and F. J. Zucker, Antenna Theory Part 2, McGraw-Hill, 1969, p. 404.

5. Malagisi, C., RADC, private communication.

6. Kraus, J. D., Antennas, McGraw-Hill, 1950, p. 321.

7. Jordan, E. C. and K. G. Balmain, Electromagnetic Waves and Radiating Systems, Prentice Hall, 1968, pp. 629-646.

8. Barrick, D. E., "The Interaction of HF/UHF Radio Waves with the Sea Surface and its Implications", AGARD Conference Proceedings No. 77 on Electromagnetics of the Sea, 22-25 June 1970, AGARD-CP-77-70.

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